ICEE 2015

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New Technologies and Innovation for Global Business

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19th International Conference on Engineering Education

July 20-24, 2015
Zagreb, Zadar (Croatia)

New Technologies and Innovation in Education for Global Business

Under the auspices of the Ministry of Science, Education and Sports

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NEW TECHNOLOGIES AND INNOVATION IN EDUCATION FOR GLOBAL BUSINESS

PROCEEDINGS

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Content

Message from the General Chair

Welcome to ICEE 2015

Professor Đuro Njavro, Ph.D., Dean

Conference Chair

On behalf of the Conference Organizers, it is with great pleasure that we welcome you to the 19th International Conference on Engineering Education (ICEE 2015): New technologies and innovation in education for global business. With Croatian Ministry of Science, Education and Sports and Polytechnic of Zagreb as our partner, we expect this Conference to offer a perfect mix of science and networking.

Croatia has a long tradition of producing engineering excellence within the institutions with a distinguished reputation of its outstanding scientists. ZSEM, as well, has hosted many international conferences with huge social and scientific impact. This particular one will continue the iNEER tradition of quality, highlighting the developments in engineering education as well as focusing on innovation, globalization and networking.

The conference aims to be the ideal platform for making international connections for future collaborations in various academics field. Also, it will allow the exchange of the best engineering practices that concern emerging areas related to entrepreneurship, management and education.

While the breadth and depth of the Conference will keep you busy, we encourage you to extend your visit and enjoy all that ICEE 2015 has to offer. Take a trip to Plitvice lakes, our oldest and most popular National Park. In 1979 the National Park Plitvice Lakes was listed on the UNESCO list of natural World Heritage. Enjoy lakes and views of waterfalls, amazing flora and fauna while driving boat and walking through the park. Furthermore, take the opportunity to visit Zadar, a city monument, surrounded by historical ramparts, a treasury of the archaeological and monumental riches of ancient and medieval times, Renaissance and many contemporary architectural achievements such as the first sea organs in the world.

Once again welcome. Welcome to the leading higher education institution in Croatia in the usage of e-learning as well as a proud holder of the Association of Advance Collegiate Schools of Business (AACSB) accreditation, Zagreb School of Economics and Management (ZSEM), welcome to Zagreb, welcome to beautiful Croatia where the great Nikola Tesla was born.

We look forward to sharing this week with you!

Conference chair

Đuro Njavro, dean, ZSEM

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Siniša Krajnović, Vice President and Head of Development Unit Radio at Ericsson

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Keynote Speakers

ICEE 2015

Keynote Speaker 1 - Krishna Saraswat

Prof. Krishna Saraswat is Rickey/Nielsen Professor in the School of Engineering, Professor of Electrical Engineering and by courtesy Professor of Materials Science & Engineering at Stanford University. He received his B.E. degree in Electronics in 1968 from the Birla Institute of Technology and Science, Pilani, India, and his M.S. and Ph.D. degrees in Electrical Engineering in 1969 and 1974 respectively from Stanford University, Stanford, CA. During 1969-70, he worked on microwave transistors at Texas Instruments. Returning to Stanford in 1971, he did his Ph.D. on high voltage MOS devices and circuits. After graduating he joined Stanford University as a Research Associate in 1975 and later became a Professor of Electrical Engineering in 1983. He also has an honorary appointment of an Adjunct Professor at the Birla Institute of Technology and Science, Pilani, India since January 2004 and a Visiting Professor during the summer of 2007 at IIT Bombay, India. Professor Saraswat's research interests are in new and innovative materials, structures, and process technology of silicon, germanium and III-V devices and interconnects for VLSI and nanoelectronics. Areas of his current interest are: new device structures to continue scaling MOS transistors, DRAMs and flash memories to nanometer regime, 3- dimentional ICs with multiple layers of heterogeneous devices, metal and optical interconnections and high efficiency and low cost solar cells. Prof. Saraswat has supervised more than 80 doctoral students, 25 post doctoral scholars and has authored or co-authored 15 patents and over 750 technical papers, of which 10 have received Best Paper Award. He is a Life Fellow of the IEEE. He received the Thomas Callinan Award from The Electrochemical Society in 2000 for his contributions to the dielectric science and technology, the 2004 IEEE Andrew Grove Award for seminal contributions to silicon process technology, Inventor Recognition Award from MARCO/FCRP in 2007, the Technovisionary Award from the India Semiconductor Association in 2007, BITS Pilani Distinguished Alumnus Awards in 2012 and the Semiconductor Industry Association (SIA) Researcher of the Year Award in 2012. He is listed by ISI as one of the Highly Cited Authors in his field.

Presentation

What Makes Silicon Valley and Stanford University Tick?

Since the early part of 20th century Stanford University has had a meteoric rise and is regarded today as a top teaching and research institution in the world. Since middle part of the 20th century Silicon Valley has developed from small towns surrounded by farmland into a leader in innovation. Silicon Valley accounted for less than 1% of U.S. population, about 12% of all new U.S. patents and 50% of all new patents coming from California in 2009. Silicon Valley per-capita income is much higher than U.S. and California averages. But so is the cost of living. How can Silicon Valley sustain such a high cost of living? What are the secretes of the success of Silicon Valley and Stanford? Till 1940's Stanford was good but not great. Stanford realized that industry-academia partnership is the fundamental element of cooperation for mutual growth. Stanford attracted many famous scientists from industry as pillars of excellence to become faculty by giving them many incentives. They were encouraged to have interaction

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with the industry. This was true not only for collaborative advanced research but also for providing practical training to students by industry, and for further development of industrial employees. Industry generally works on focused execution of technology R&D, and to bring technology to manufacturing floor and thus is in competitive mode for value differentiation for unique technology, unique products and time-to-market. On the other hand academia works on creation of new idea to proof of concept. The industry academia collaboration is best in the non- and pre-competitive mode with knowledge and resource sharing across broad spectrum of organizations, institutions and countries for critical mass. Stanford has been at the forefront of such collaboration with the industry. How do we educate students today beyond conventional methods? We develop them into T-shaped people with breadth of knowledge about entrepreneurship, creativity, and innovation and depth of knowledge in a specific discipline. As a result Stanford faculty and students have been instrumental not just in generating knowledge but also inspawning very successful startups through innovation and grow them into large companies. Silicon Valley thrives via an innovation-based entrepreneurial economy. It is a robust engine for new company creation. Necessary elements of an innovation-based, entrepreneurial economy are dynamic coming together of people, ideas, capital, and infrastructure. Well-known characteristics of Silicon Valley are results-oriented and risk-taking social values, highly educated and mobile workforce, R&D activities in many technology areas, concentration of venture investors, fascination with, and flexibility to reinvent itself around “the next new thing”, strong supporting human infrastructure(lawyers, accountants, technology and marketing consultants, executive search firms, etc.), and last but most importantly a very strong industry friendly Stanford University. Stanford has been an important part of the meteoric rise of the Silicon Valley. Stanford’s relationships with industry encourages innovation for real products, collaboration on pre-competitive technology and human networking. In this talk we will explore the reasons of the mutual success of Stanford and Silicon Valley with several examples.

Keynote Speaker 2 – Siniša Krajnović

Dr. Krajnović is a senior executive in Ericsson with more than 10 years of international management experience. Since 2011 he has been living in Stockholm, Sweden. He works in Ericsson as Vice President and Head of Development Unit Radio, leading a global development organization consisting of 10+ R&D centers and 12,000+ engineers. Sinisa earned his PhD degree from the University of Zagreb, Croatia, and completed executive education programs at Columbia University (US), IMD (CH), Cranfield University (UK) and ISB (IN). He is Professor at the leading business school in Croatia, Zagreb School of Economics and Management, and Program Director of their General MBA Program. Sinisa has extensive multicultural experience and understanding gained through living and working in Croatia, UK, Ireland, Japan, Hungary and Sweden.

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Keynote Speaker 3 – Petar Jandrić

Petar Jandrić (PhD) is tenured Senior Lecturer in e-Learning and Director of BSc (Informatics) programme at the University of Applied Sciences in Zagreb (Croatia), visiting Associate Professor at the University of Zagreb (Croatia), professor and Director of Institute for Research and Knowledge Advancement at the Global Center for Advanced Studies (Michigan, US). His research interests are focused to the intersections between critical pedagogy and information and communication technologies. Research methodologies of his choice are inter-, trans- and anti-disciplinarity. Petar's previous academic affiliations include Croatian Academic and Research Network, National e-Science Centre at the University of Edinburgh, Glasgow School of Art and Cass School of Education at the University of East London. He writes, edits and reviews books, articles, course modules and study guides, serves in editorial boards of scholarly journals and conferences, participates in diverse projects in Croatia and in the United Kingdom, regularly publishes popular science and talks in front of diverse audiences. His major current projects are focused to collaborative research and editing.

Presentation

Critical teaching as hacking the neoliberal agenda

Hacking cannot be thought of without learning. Actually, it can be said that hacking is a true celebration of learning and empowerment / emancipation resulting from learning and knowledge. Certainly, hackers' views to learning and knowledge are very different from those used in traditional educational systems. According to McKenzie Wark, "hackers desire knowledge, not education. The hacker comes into being through the pure liberty of knowledge in and of itself. This puts the hacker into an antagonistic relationship to the struggle on the part of the capitalist class to make education an induction into wage slavery" (2004: 55). Such normative positioning puts the hacker culture in direct opposition to prevalent neoliberal agenda characteristic for worldwide schools and governments; it also provides the hacker culture some valuable allies such as the critical pedagogy movement.

Using digital technologies in teaching and learning is predominantly linked to the neoliberal agenda. Indeed, it is hard to deny that usage of tools such as e-mails and virtual learning environments contributes to Ritzer's four primary components of McDonaldization of education: efficiency, calculability, predictability, and control (2012). However, tools such as peer-to-peer and / or pre-publication networks can aim exactly the opposite and serve as subversions (i.e. Vuković Peović, 2015; Ralston, 2015). Certainly, Gramsci's teachers as organic intellectuals (Gramsci, 1992) or Giroux's teachers as transformative intellectuals (Giroux, 2012) reject the neoliberal agenda which is almost sub-consciously peddled alongside digital technologies. However, sporadic subversions are only the tip of the ice-berg, and we need to permanently hack the neoliberal agenda through creative usage of digital technologies for social transformation. In contemporary digital technoscapes, critical teachers need to wear one more coat – that of teacher-hackers or hacker-teachers.

This talk explores theoretical intersections between the hacker culture and the critical pedagogy movement. Based on analyses of shared values and practices, it inquires what it means to be teacher-hacker in the contemporary society.

Workshop

ICEE 2015

Teaching technology entrepreneurship at engineering universities - experiences, perspectives, challenges and assessment

Author

Sergej Lugovic is a senior lecturer teaching Information Economy, Technology Entrepreneurship and e-business at the Polytechnic of Zagreb, Croatia. He's also a PhD student at the Information Science department of the Faculty of Humanities and Social Sciences, University of Zagreb. His research interests are information behavior and needs in intelligent socio-technical systems. He holds a Master of Science degree from Plekhanov Russian University of Economics and an MBA from The London College UCK. Along with his academic career, he had a business career in Moscow, London, and Zagreb, working for blue chip companies, for the government of the Republic of Croatia, in technology ventures, and in the fashion and the music industries.
He introduced the subject "Technology Entrepreneurship" to the Polytechnic of Zagreb and edited the Croatian version of the textbook Technology Ventures published by McGraw-Hill and used at Stanford University in the US, among others.

Workshop Purpose

The aim of this workshop is to exchange experiences in teaching entrepreneurship and/or other business topics to engineering students. The workshop will encourage open discussion between participants regarding how to assess teaching, what the challenges are for teachers and institutions, and what teaching perspectives are applicable.

Workshop Description

Technology entrepreneurship is a relatively new discipline, finding its place in curriculums of engineering universities around the world, in particular in the United States. It addresses how entrepreneurs capitalize on technology changes. At the same time, it's relevant for the new technology-based firms (NTBFs) as well as incumbent technology-based firms (ITBFs) teaching students how to use scientific and technological knowledge in the real global marketplace.

Business and economics universities usually teach entrepreneurship. Today, however, for technology-dependent business operations using engineering and scientific advances, university research units and companies are exploring paths to capture research results and transform them to value for the customers. We will ask the question about importance of teaching entrepreneurship skills to engineering students.

We can apply different teaching perspectives, and for the purpose of the workshop, we will use the following: transmission (subject content transmission), apprenticeship (behavioral norms and way of working), development (from the learner's point of view), nurturing (achievements comes from the heart, not head), and social reform (the impact on society) (Pratt & Collins, 2000). Another important related issue is what

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challenges universities face today, in particular, when teaching entrepreneurship to engineers.

We see radical shifts in the academic environment, where incubators and accelerators backed by financial industries and large companies are providing education around their products and services to deliver fast-track education. At the same time, new alternative models such a crowd-funding, share economy, and outsourcing are emerging. This leads to another important question, one that opens inquiry about assessment methods. Should we address how students perform in terms of financial and business results? Should we assess how they understand the body of knowledge? Should we observe how they behave and adapt in a real business environment, or should we evaluate their decision-making processes?

Workshop participants are invited to openly share their experiences and afterwards participate in a relevant conversation. The output of the workshop will be meeting notes, which will circulate to all participants with the option to publish them as a paper after post-workshop iterations.

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Panel

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Ideas to Big to Stay Small: Two cases of tech startups in Croatia with Double Bottom Line Impact

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Abstract

Purpose – The purpose of this panel is to illustrate the trajectory of ideas that are conceptualized for greater impact beyond their borders. The cases originating from Croatia, one of Teddy the Guardian, a high tech teddy bear that aids in child patient diagnostics and the other, Serwantess, a device that improves quality of life for home-bound patients are examined as both have customer markets that extend well outside their country of origin. Design/methodology/approach – Two enterprises with innovations in healthcare are explored through in-depth interviews with their founders as well as data collected from secondary resources. Their stories are unpacked using Isenberg's Domains of the Entrepreneurship Ecosystem as a framework. The startup ecosystem assessment is seen from their perspective to reflect the accelerators and inhibitors to their growth and development. Findings – The two cases showcase the opportunities and threats of big ideas coming from small markets. Lessons can be learned on how to create an environment that assists tech startups in navigating multiple stakeholders. The double bottom line impact includes social, they are improving the care of patients and financial, whereas and generating investments and sales internationally. Originality/value – This panel provides real value by focusing on two emerging startups that launched within the past five years with rapid traction made possible by focusing on solutions to universal problems.

Keywords: Entrepreneurship, Social Impact, Tech Startups, Healthcare

AOL, PBL and Quality Assurance

ICEE 2015

Development and Uses of Iterative Systematic Literature Reviews in Electrical Engineering Education

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Abstract

It is expected that most, if not all, graduate students will posses skills necessary for doing literature reviews. It is less clear how to teach these skills most effectively especially to students who are area novices and unfamiliar with review process. Systematic literature reviews offer a solid instructional framework which can be implemented across curriculum and offer an opportunity to teach course material differently so that student learn not just the literature review technique itself but also some segment of the course material. Our pilot study investigated issues related to practical implementation of systematic literature reviews in two classes, with different course lengths and purpose of review assignments. Our initial results are encouraging: students' self-efficacy with respect to ability to do reviews improved and they think that this skill is useful. We have developed a new rubric for evaluation of final reports as well as weekly schedule of tasks.

Keywords: *systematic literature reviews, rubrics.*

1. Introduction

Literature review is a skill that most faculty would profess all research-oriented graduate students should have. Students can typically acquire this skill through a) mentoring, and/or b) course on research methods. The latter can be generic or taught within a department. There are many resources on writing literature reviews, from campus writing centers to books such as Machi and McEvoy [1]. One would also assume that this is among the very first tasks that research-oriented students would undertake. However, our brief and preliminary survey of students in two graduate courses in electrical and computer engineering department showed that they have very little to no experience in performing literature reviews, and discussions with other faculty confirmed that students in their classes are equally unprepared. The most obvious use of training graduate students in performing literature reviews is in helping them write their thesis or dissertation. Literature reviews, however, have other uses, such as starting a new research area by identifying holes in the existing literature or summarizing one's own research area. It has also been argued that a variant of literature review, so-called "systematic literature review" (SLR) can help students publish their first original work and transition them from novice to knowledgeable [2][3]. Finally, systematic literature reviews are research area by themselves, although they are less common in engineering than in areas like medicine, psychology or education.

It is, therefore, appropriate to intentionally train and educate students in performing literature reviews in general and SLR in particular. One possible approach is to design a research methods course that also covers SLR topics or maybe even have a separate course or workshop on SLR. Experience with other so-called soft-skills, such as technical writing, suggests that learning how to do literature reviews and SLR can best be accomplished by incorporating them in various courses across the curriculum and not by designing a separate course [4]. In this report, however, we will concentrate on the course-level implementation. Furthermore, there seems to be a lack of familiarity among engineering faculty regarding differences between narrative and systematic literature reviews (SLR). In this report we will clarify the differences and explain uses of SLR in different fields and how it could be used in engineering education.

In the following we will present the case that iSLR is a useful educational tool in electrical engineering when used either as part of research-like project on a specific subject matter covered in a course, or as a standalone project. Expected educational benefits include improved critical thinking and writing, increased motivation, life-long learning skills, increased topic coverage and depth. We modified two graduate courses to include SLR: a) solid-state electronics course for MS and PhD electrical engineering students, and b) microwave circuit design sequence for graduate students and undergraduate seniors. The rest of the paper is organized as follows: section 2. gives an overview of uses of SLR in other disciplines, section 3. discusses iSLR implementation, section 4. presents some assessment data and analysis, and section 5. provides conclusions.

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2. Systematic literature reviews in different disciplines

A lot of resources are available for writing literature reviews and there are general and field-specific books that cover the process, e.g. [1]. Typically, these books are aimed at graduate students preparing their theses or dissertation proposals, but they do not discuss SLR- or iSLR-based approaches. Given that the use of SLR or iSLR as a pedagogical tool is relatively recent, it is important to properly distinguish SLR from other forms of review and to understand where it comes from, its history, and how it is used in different disciplines. One discipline using SLR extensively is medicine where the purpose of SLR is not to just summarize the state-of-the-art at a given point in time, but also to provide meta-analysis of available data, which then leads to some conclusions and policy decisions. Given the potential impact and importance of such studies, there was a need to provide specific guidance with respect to how such studies should be performed and reported, resulting in two statements: QUORUM (Moher et al. [5]) and PRISMA (Moher et al. [6]). PRISMA statement defines SLR as:

> *A systematic review is a review of a clearly formulated question that uses systematic and explicit methods to identify, select, and critically appraise relevant research, and to collect and analyze data from the studies that are included in the review. Statistical methods (meta-analysis) may or may not be used to analyze and summarize the results [6].*

The PRISMA statement provides guidelines on seven areas that SLR studies should address: Title, Abstract, Introduction, Methods, Results, Discussion, and Funding. There is a total of 27 items in a checklist format. For example, it is required that an SLR study:

- *Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.*
- *State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis) [6].*

In software engineering procedures and guidelines on how to conduct SLR have been available since 2004 [7][8] and there is a similar attempt to define SLR:

> *A systematic review is a means of evaluating and interpreting all available research relevant to a particular research question, topic area, or phenomenon of interest. Systematic reviews aim to present a fair evaluation of a research topic by using a trustworthy, rigorous, and auditable methodology [7].*

While their emphasis and wording is different, both definitions are attempting to explain what “systematic” means and implicitly distinguish such studies from other approaches to literature review.

Most engineers and engineering educators are more familiar with a different kind of literature review: narrative review. Narrative review is meant to provide an overview of a given field and is written by a recognized expert in that field. Compared to a systematic literature review, the main differences lie in the areas of problem definition and methodology. Table 1 is adapted from the field of evidence-based medicine [9] and it summarizes the main differences between the two review approaches.

Table 1. Summary of main differences between systematic literature reviews and narrative reviews.

Systematic Literature Review	**Narrative Review**
Investigates a clearly defined research question.	Provides an overview of a research area
Literature is gathered using explicit and systematic search protocols.	Explicit, systematic literature search protocol is not used.
Studies are selected using a protocol that specifies inclusion and exclusion criteria.	Inclusion and exclusion protocol and criteria are not specified.
Data from primary study may be synthesized in a meta-analysis. Strength of evidence is assessed for individual studies.	Strength of evidence may be assessed for individual studies.
When evidence is lacking, the authors usually recommend further research.	When evidence is lacking, the authors make recommendations based on their opinions and experience.

Systematic literature reviews can be used to advance a given research field. For example, Borego et al. [10] argued that the field of engineering education research would benefit from more SLR reports. They also

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provided a very useful and detailed explanation of methodology for proper application of SLR in engineering education research and pointed out that "... narrative reviews differ from systematic reviews in that the identification and selection criteria for sources are usually implicit; narrative reviews typically do not include methods sections" [10]. Therefore, usefulness of SLR as a research tool is well established but its application in engineering fields appears to be lagging behind other fields, such as medicine. Attempts to establish SLR as pedagogical tool are more recent and are discussed next.

2.1. SLR as Pedagogical Tool in Engineering

There are not very many reports of SLR use as a pedagogical tool in engineering education and it seems that it was first used in this fashion in the software engineering area. The most recent report in [11] discussed development of *iterative* SLR (iSLR) and its educational benefits, while an earlier study [12] described successfully teaching undergraduate students some software engineering skills and concepts. One attractive feature of iSLR process is that it is flexible and allows for refinement of results at various stages in the process. This flexibility makes it suitable for novices in a given area of study because their understanding of the problem and process improves as they perform SLR. Studies in [11] and [12] have established that iSLR can successfully be performed by area novices. In our pilot study we followed procedures discussed in [11] with a few modifications, as discussed below.

There are eight stages in the iSLR process [11] as shown in Figure 1.

Figure 1. Stages in systematic literature review process.

The usual SLR practice is modified in iSLR by allowing iterations between different stages. For example, finding too many references during the initial search (stage 3.) may indicate that the question (stage 2.) was defined too broadly and needs to be modified. One modification that we introduced deals with the *Search strategy* stage. Instead of letting students come up with search strings right away, we provide them with one seed article that they use for forward and backward *snowballing*, i.e., looking up references cited in that article and looking up papers citing that article. In this way students can gain better understanding of the context of the problem, learn the conventions and language of the specific sub-area, examine keywords used in the article etc. This eases them into the heart of the problem and helps them formulate the initial question.

3. Implementing iSLR

Our first implementation of iSLR was done in a Solid-State Electronics I graduate course, which is taken by MS and PhD electrical engineering students. The course covers many common solid-state physics topics such as band theory of semiconductors, conduction in metals and semiconductors, and carrier transport in classical and semi-classical approaches. Within this course, students undertook experimental characterization of very thin metal films using THz Time-Domain-Spectroscopy (TDS) methods as a research project. This naturally led to an iSLR project related to literature on the topic of "TDS characterization of thin metal films." A total of seven students took the course in the Fall 2014 quarter, and they were divided into three teams (2+2+3). Each team was given a different starting paper. Initial results from this implementation have been reported in [13].

In Winter 2015 quarter, we ran another version of iSLR in Microwave Circuits Design I course which has a follow-on 2nd part in Spring quarter. Both undergraduate seniors as well as graduate students take this course but

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at this time only graduate students are required to undertake iSLR. During the first 10-week long quarter we cover passive microwave devices while in the second quarter we discuss microwave amplifiers and other active circuits. In this course we approached the iSLR assignment differently: a) students were allowed to chose their own topic, and b) there was no experimental component that related directly to the topics students selected. This approach makes it more difficult to directly integrate the content of the iSLR project into the course but it retains all the other educational benefits and better motivation stemming from students' choice of their own topic. A total of 11 students were divided into four groups (2+2+3+4).

In both courses each team was set up as an online group in Zotero [14] so that students could share papers they found and do the sorting using directories and annotation features provided by Zotero. This made collaboration on paper search and selection very easy and transparent. For example, each student can have their own directory with papers assigned to them for further reading and within that directory they can further sort papers according to specified selection and quality criteria. Tags and keywords associated with each paper can be used to further group papers once the core idea and subtopics are established. One very useful feature of Zotero is the ability to pull bibliographic information and paper directly from database webpage. This greatly speeds up the search process and students quickly master it.

In order to define a weekly schedule, each stage in iSLR is broken down into a more detailed list of specific tasks, e.g., for items *3. Search strategy* and *4. Selection process* we have:

a) Perform snowballing search from the starting paper and deliver
   a. Raw list of references, (this should be exported from Zotero in some electronic format for future inclusion in written documents)
   b. Selection criteria for eliminating / keeping papers from that list
   c. List of references after selection; each eliminated paper should have a comment or code explaining why it was eliminated.
   d. <u>Suggestions for possible refinement of research question</u>

b) Perform database literature search based on keywords and deliver:
   a. Raw list of all papers
   b. Selection criteria for eliminating / keeping papers from that list (can be the same as the one used for snowballing)
   c. List of references after selection; each eliminated paper should have a comment or code explaining why it was eliminated.
   d. <u>Suggestions for possible refinement of research question</u>

c) Combine references from a) and b) into a single list

Underlined tasks indicate opportunities for iterative improvement of the research question – the "i" in iSLR. Based on this list a weekly schedule specifying tasks and deliverables was developed. For example, in a 15-week schedule students are given the following tasks in weeks 5 - 7:

Week 5:
- ☐ Do a selection of all the acquired papers based on stated criteria
  - o Separate papers on Zotero into directories – one for further reading and one for rejected papers
  - o Submit on D2L a list of papers you: a) examined, b) accepted and c) eliminated

Week 6:
- ☐ As group, divide the references from snowballing and continue working on selection and annotation
- ☐ Revisit selection criteria now that you have collected more papers
- ☐ As a group, produce a draft annotated list from snowballing
- ☐ After you have watched librarian's presentation
  - o Decide as a group which search string you will use
  - o Perform database searches and explain why you used certain databases and not others
  - o Store papers in Zotero for further processing

Week 7:
- ☐ Finalize the problem statement (last chance to refine it)
- ☐ Divide the list of papers from database search among group members
- ☐ Perform selection (use titles, keywords and abstracts)
- ☐ Annotate and code ("tag") papers as selection is done
- ☐ Assignment for next week:
  - o Report the total number of papers found and number of eliminated ones
  - o Produce a diagram explaining the core idea or concept and how it is divided into sub-topics.
  - o List themes that you observed, if applicable.
  - o Report on how you are doing coding, i.e. which tags are used.

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The end of week 7 is roughly where the first part of iSLR is finished and it coincides with the end of first quarter in a two-quarter course sequence. Students are required to produce an interim report consisting of these sections: Summary, Introduction, Division of Labor and Zotero Use, Research Question, Snowballing Results, Database Search Setup, Selection Process and Annotated Bibliography. Total length should be from three to four pages, excluding the bibliography. This breakpoint and interim report would also be recommended for a semester long course but is difficult to fully implement in a single 10-week long course.

4. Assessment

In order to gauge effectiveness of SLR projects as educational tool, we assessed several items:

a) Student self-efficacy in doing literature reviews before and after iSLR project
b) Quality of iSLR reports
c) Identifying major problems or roadblocks to successful implementation of iSLR

Pre-course survey was done at the beginning of the course to establish students' familiarity with any type of literature review process. As Table 2 shows, 13 out of 16 students have done literature review of any kind only once or never. Even lower numbers are reported for literature reviews in technical fields, i.e. sciences and engineering. However, results in Table 3 seem to indicate that students are reasonably confident in their ability to do literature reviews. For example, 12 out of 16 selected strongly agree, agree or are neutral when asked how confident they are they can do a literature review on their own (item 3.). This seems at odds with students' lack of experience in doing literature reviews. We believe that these results indicate poor familiarity with literature review. Conversations with other faculty provide anecdotal support for this observation, i.e., that students are generally unprepared to perform literature reviews. Table 3 also indicates that almost all students believe this skill will be valuable in their education or work.

Table 2. Students' frequency of use of literature reviews prior to SLR project. Both courses included

	Never	Once	Twice	3 or more
Literature reviews done in any field	6	7	1	2
Literature reviews done in technical fields	8	5		2

Table 3. Student self-efficacy for ability to do literature reviews, pre-SLR project. Both courses included.

	Str. Agree	Agree	Neutral	Disagree	Str. Disagree	Not Appl.
1. I am familiar with literature review process		5	4	2	5	
2. I can explain various stages in literature review		2	3	6	5	
3. I am confident that I can do a literature review on my own	2	3	7	2	2	
4. Learning how to do literature review will be valuable in my studies	5	10			1	
5. Learning how to do literature review will be valuable in my current workplace	3	9	2			2

In another report [13] we analyzed changes in student self-efficacy by comparing pre- and post-project survey results but only from one course. Early indications are that student self-efficacy improves after SLR project but their judgment of usefulness of SLR declines. We also found that the *Selection* stage was the most time consuming while *Question formulation* was the most confusing. Finally, *Synthesis* stage needed to be explained much better in class.

4.1. SLR report assessment rubric

Rubrics are widely used and there are many books and other resources devoted to their development, e.g. [15]. In our other courses we have found rubrics to be very helpful in grading. In addition, they lead to better and more consistently assessment of the quality of submitted reports and provide more useful feedback to students, especially if they are included as part of the assignment. At first, we adapted an existing rubric, which was developed for assessment of general literature reviews [16]. Among the three reports in ECE 511, one was assessed to be between Developed and Exemplary, one was Developed and one in between Average and Developed. This was deemed to be a very good performance for a pilot study. However, it quickly became apparent that this rubric needed to be substantially revised to address items related to iSLR process and to make it more applicable to the type of writing usually done in technical reports.

Tables 4 and 5 present our first attempt at designing an iSLR report rubric. It is split in two parts because the project runs across two quarters and interim report is required. At this stage students have finished the *Selection* stage which enables them to write an annotated bibliography. Therefore, the first part is very specific in terms or requirements and the way they are assessed. This should help students write good reports even without initial drafts. This expectation was confirmed in our first application of it during winter 2015 quarter when all of the submitted reports met or exceeded expectations. However, the second part is more challenging both in terms of critical thinking required as well as writing. This is reflected in the criteria and performance levels listed in Table 5 which are less specific and rely more on evaluator's experience and judgment. Nonetheless, they cover areas that we have found useful in assessing previous set of reports. As of this writing, we do not have the results from the second course – those will be presented at the conference.

Table 4. Systematic literature review report rubric - part 1.

Criteria	Does not meet expectations	Approaches expectations	Meets expectations	Exceeds expectations
Format	Does not follow specs	Follows specs but sloppy	Follows all specs; has all the required parts	
SLR process	Procedures not followed and misunderstood	Procedures followed but some parts misunderstood	Procedures followed	Complete and detailed understanding of SLR demonstrated
Research question	1. Trivial question with little thought put into it 2. No evidence of revision	1. Acceptable question but poorly posed 2. Some evidence of revision	1. Relevant and clear question 2. Clear evidence of revisions	Original way to pose a question that shows deep understanding of the field
Selection	1. Arbitrary selection 2. No clear criteria given 3. No evidence of use of criteria	1. Few criteria given but some are unclear 2. Some evidence of use of criteria	Clear and relevant selection criteria given and utilized	Novel and unexpected ways of defining criteria and applying them
Annotated Bibliography	1. Does not follow IEEE format 2. Number of papers is too big or too small 3. No annotation or it does not make sense	1. Follows IEEE format 2. Number of papers is reasonable 3. Most annotations are sensible	1. Follows IEEE format 2. Reasonable number of papers 3. Clear and sensible annotations	Detailed annotations that would enable a serious research project in a given area

5. Conclusions

Our pilot study was limited in scope and it aimed to replicate some earlier findings and to demonstrate that:

a) iSLR is a very promising methodology that provides a framework for teaching students **both** the methodology of systematic literatures reviews as well as material relevant to the course in question
b) Implementation is not onerous
c) Students benefit from performing iSLR.

We have implemented it in two graduate-level courses along with detailed schedule of tasks, requirements and assessment rubrics. Initial results indicate good student performance and improvements in self-efficacy but we have yet to collect all the data. The study is limited by the relatively small number of students involved and will have to be expanded to other courses, instructors, departments and institutions. We hope that more instructors will decide to experiment and implement the methodology presented here and we would welcome collaboration on its future development.

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Table 5. Systematic literature review report rubric - part 2.

Criteria	**Does not meet expectations**	**Approaches expectations**	**Meets expectations**	**Exceeds expectations**
Report outline (Abstract, Introduction, Methods, Results, Synthesis, Annotated bibliography)	1. Significant sections of the report are missing	1. Most sections of the report are present 2. Distinction between sections or their content is not appropriate	1. All sections are present and have appropriate content	
Organization (research question, core idea, subtopics)	1. Research question and core idea not established 2. Subtopics either not present, too specific, too broad or not appropriate	1. Research question and core idea vaguely described 2. Subtopics present but do not follow logical sequence or are inappropriate	1. Research question and core idea clearly outlined 2. Most subtopics are appropriate and follow logical sequence	1. Research question and core idea clearly outlined 2. All of the literature discussion organized into appropriate subtopics, which follow logical sequence
Literature analysis (strength of evidence, relevance and importance, systematic application)	1. Quality criteria not defined. 2. Relevance and importance of individual studies not discussed. 3. Relationship among studies not discussed. 4. Analysis not applied systematically.	1. Quality criteria defined but not applied consistently. 2. Relevance or importance of some individual studies partially established. 3. Relationship among studies cursorily examined. 4. Systematically applied to small segment of the literature.	1. Quality criteria defined but not applied consistently. 2. Relevance and importance of most studies partially established. 3. Relationship among studies partially established. 4. Systematically applied to most of the literature.	1. All of the components fully satisfied, clearly explained and supported by the discussion of the literature.
Contribution and rationale	1. Contribution of current review not stated. 2. Stated rationale is unclear or follows poor logic.	1. Contribution stated but not clearly. 2. Rationale stated but not supported by discussion of the literature.	1. Contribution clearly stated but not fully supported by the literature. 2. Rationale stated and marginally supported by discussion of the literature.	1. Clear, logical explanations for contribution and rationale established. 2. Contributions and rationale are supported by the literature.
Clarity of writing	1. Writing style not appropriate for literature review. 2. Frequent grammatical and spelling errors. 3. Inconsistent voice.	1. Writing style is appropriate but occasionally unclear. 2. Occasional grammatical or spelling errors. 3. Inconsistent voice.	1. Writing is appropriate, clear and free of grammatical and spelling errors, and expresses single voice.	1. Writing is appropriate, clear and free of grammatical and spelling errors, and expresses single voice. 2. Writing style enhances the impact of the conclusions.
Overall quality	1. Report has a feel of a rush job with as little effort as possible put into it. 2. Many little problems and a few big ones.	1. OK overall quality that students would not be ashamed to share with their parents.	1. Excellent quality so that students would want to include it in their portfolio of projects to show potential employers.	1. Publication quality.

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Some Insights to Quality Improvement in Engineering Education System

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Abstract

The content of this paper is to recall some facts about the application of the quality system in the academic sector. The goal of the application of the quality system at the University is not only to ensure the quality of teaching, but gradually improvement at all levels of management and organization that will lead to raising the professional level of students. Quality is often used words about, but many people are unaware of its real meaning and, above all, its application in practice. Fortunately, there are practical experiences and results from the manufacturing sector, where after the Second World War, Japan was able to turn the theory of Edward Deming in the economic miracle. As a result, then a series of quality systems, which have been and still are successfully used in a number of companies, for example ISO, TQM and others. Unfortunately, in the academic sector is no uniform system of quality and there is a question whether he could in the realty exist. Detection and monitoring data is full responsible and fundamental step in all quality systems. There are some options, but for its successful introduction, several conditions must be met, which are mentioned in this paper. It is emphasized that the human factor in the educational process is prevailing indicator compared to the manufacturing sectors, where are measurable errors and non-conformed products. Understanding the basic principle and the importance of the quality system is the first step of its implementation. This paper outlined some basic principles related to the application of the quality system at the university. It must be understood when the quality system is correctly applied, brings both process improvement and also increasing of their efficiency.

Keywords: *Engineering Education, Education System, Quality. TQM, ISO*

1. Introduction

In the area of quality two basic facts should be good to understand. Firstly, what quality means, and secondly, what is the significance of the quality system in practice. Just as in the manufacturing sector are is trying to achieve the highest possible quality, it is desirable to enhance the quality in the educational process too.

There are various definitions of quality but one has significant importance with worldwide impact, which defines ISO 8402-1986 standard. The quality is defined as “the totality of features and characteristics of a product or service that bears its ability to satisfy stated or implied needs”. If we assume that the educational process is a service and its output are students with their knowledge, here are the first satisfied the prerequisites for the introduction of quality in the education system. At the same time it is also fulfilled the second part of the definition, which can be understood, so that the graduates of the University, as the resulting product, must meet the requirements on the highest possible level of future employers.

Also other definitions of quality can be thought of in the context of the education system, such as for example how good or bad something is, or a characteristic or feature that someone or something has, or something that can be noticed as a part of a person or thing. Finally quality means also a high level of value or excellence.

The fundamental step leading up to the introduction of the quality system is understanding of its practical impact. It can be described briefly and concisely as a system that provides two basic requirements: continuous improvement and cost savings. It is indisputable that meet both objectives is the desire of all. The difference is in the way of achieving this. A different approach between firms and universities can occur on both these requirements, because the education sector is supported by the majority of public funds against companies that have to finance themselves. Therefore, the management of funds has a different character than in manufacturing companies. There should perform an important role in the ministry, which controls the education sector. Find the right way requires an understanding of principles and rules of the quality system, and also how the quality system is applied.

There are to resolve two major problems for quality system implementation into the educational process. The main problem number one is how to evaluate the quality of the educational process and second one is how to implement improvements including cost saving into the University or Faculty development. The basis for the ability to solve both these problems is to understand the functioning of the quality system. Then it can achieve effective and efficient use of resources in education sector, as well as ensuring of high quality by education students.

2. What means quality system in higher education

The quality system can be defined as the organizational structure of the entity (company, institution, etc.), with job descriptions that are necessary for the establishment and implementation of quality management. The base is an organizational chart describing the activities for each position, including requirements for their occupancy. There's the question, what level the quality system can be applied in education sector. In practice there are several possibilities. If we assume the existence of international standards, the quality system can act according to the diagram in Figure 1. The quality system but can be applied from the lower level, also only for the faculty. Here the question is, what brings quality system implementation at the faculty? The answer is a higher requirements for economical use of resources, and also the ensuring of high quality of student learning.

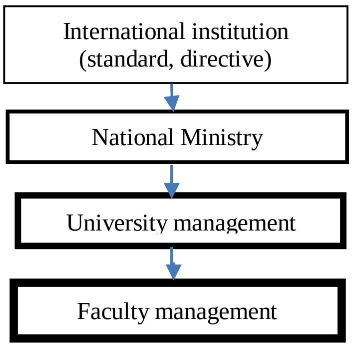

Figure 1. Position of Quality management in the Faculty

It is apparent that where the quality system should be implemented, there must also exists quality management. This is the first prerequisite for the implementation of quality system at the university. And this quality management must be connected in an organizational chart directly with the head of university (faculty), and have his full support, how is shown in the example of faculty level in the Figure 2.

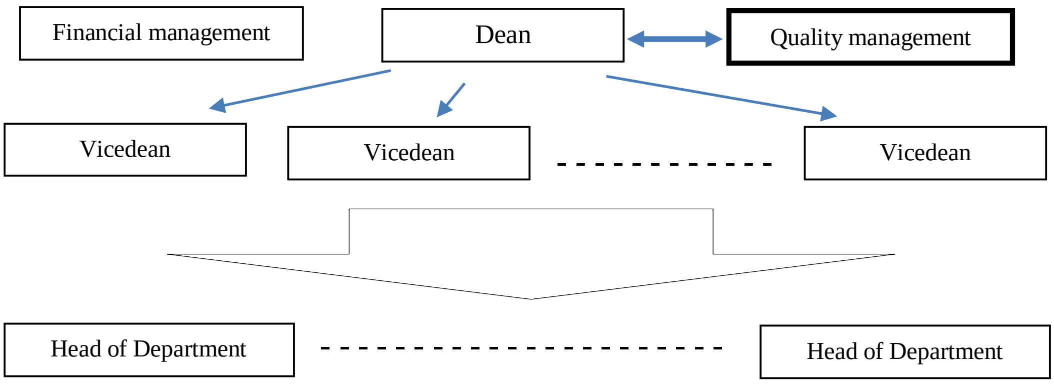

Figure 2. Position of Quality management in the Faculty organizational chart

A comprehensive quality system contains three basic areas:

- Quality planning
- Quality control
- Quality improvement

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All of these areas are part of quality management in close cooperation with the dean and with department of financial management, which are coordinating the cooperation with single departments. The quality system must define all processes, from staffing to the structure of subjects including their material assurance, and also a final evaluation of students and their subsequent employers. Improving the quality of production is most often assessed by the number of failures expressed in ppm. In the education system, this may be the evaluation of students and their employers who evaluate students' knowledge.

3. How does the system of quality in education process

The term of quality is now often used at universities, but the ideas are diverse. Improving quality is often presented as a remedy deficiencies or changes in processes, which results in changes in the education system. Three different ways of influencing the learning process are shown on Fig.4. Good and effective quality system causes not only changes but leads to improve. It must be clearly documented.

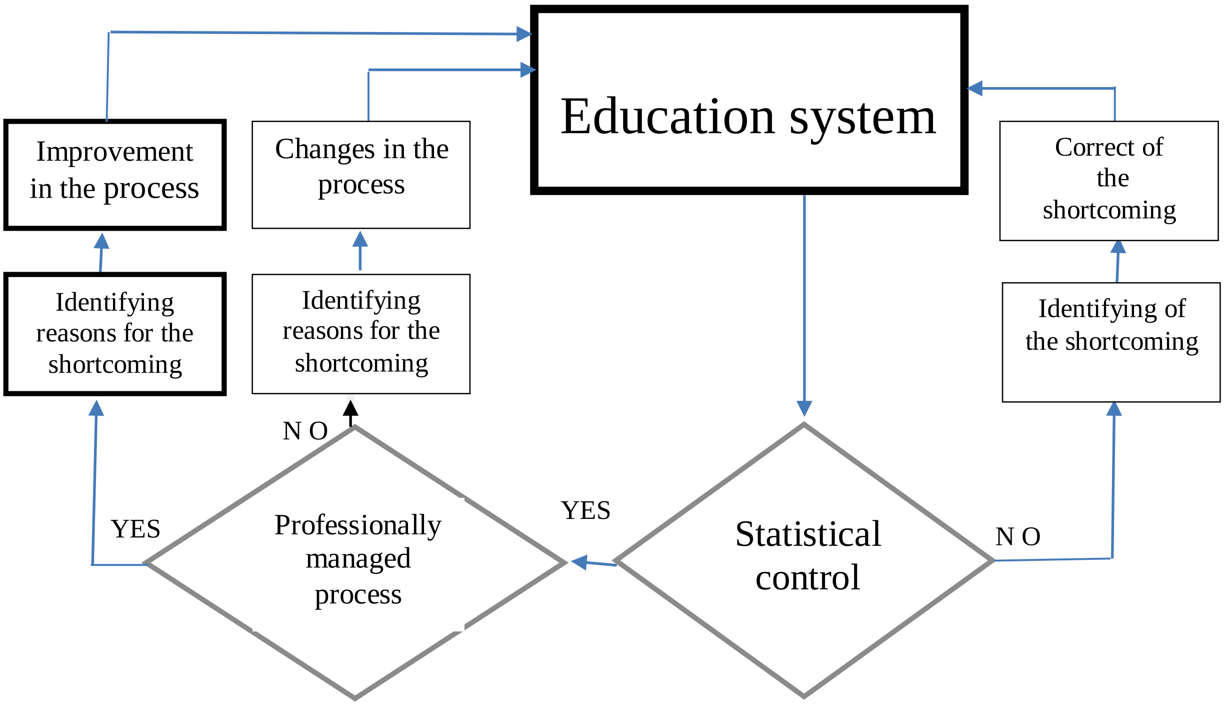

Figure 3. Depiction of different ways of managing the educational process

From Figure 3 it is evident that the main aim of quality management system is to achieve real and demonstrable improvements. This means a system for monitoring data that are measurable and comparable must be created. Data can be obtained internally from students and teachers, or externally from companies and institutions, for example evaluation of publications. Determination of criteria for obtaining data from education process is a crucial part of the quality system, because unlike the product depends on the human factor. Here, the main task is to convince all those who are involved on providing data that results will benefit them. We can ask what benefits it can be. In short, for students the higher quality of study programs, more support for teachers in the educational process and the feeling of satisfaction for their work and for businesses students with better knowledge.

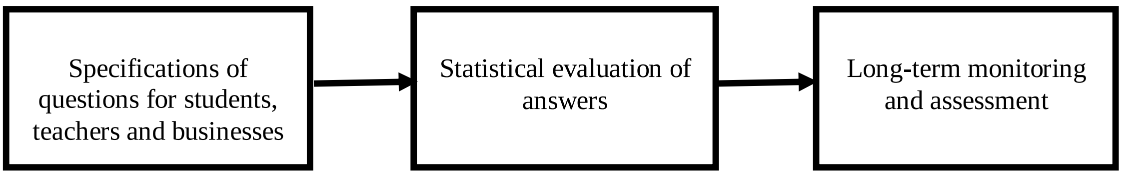

Figure 4. Structure and procedure of data processing

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Based on experience, creation of documentation for the quality system of the educational process may be similar to documentation generation for Total Quality Management in company [2], which demonstrated good efficacy in a number of institutions in different sectors. From the basic point of view of process monitoring are usually sufficient three protocols as shown in Figure 4.

From all this it is clear that the quality system must be fully supported from top management (in the case of university by rector and vice-rectors, in the case of faculty by dean and vice-deans), and then also must involve all staff and students. And there is one important principle, staff, and students must know what benefits it will bring them.

Detection and monitoring data is full responsible and fundamental step in the quality system. It must be focused primarily in three groups on:

Data from students:

- expression of students about meet their expectations,
- expressing of students about the contents of subjects,
- teacher evaluation.

Data from teachers:

- interest and participation of students in the particular subject
- material conditions of subject insurance and companies support,
- personal satisfaction,

Data from business:

- evaluation of students,
- level of collaboration with university,
- request for students and their skills.

Part of the quality system may be a variety of other data. For example tracking investment purchase and use or monitoring and evaluation of teaching, research activities etc. The parts of quality system control are also additional steps that must lead to administrative simplification, including a credible job description. We must be careful to avoid an increase in unnecessary administration in the creation of each new quality system

4. How could be implemented the quality system at the University

Implementation of quality rules into the educational system has some similar factors as its implementation in other processes generally, but also some specific rules and differences. The most used quality systems are in industry for example International Standards ISO or successfully applied complex management method TQM. The main difference is that the company must recover the invested funds, while University as non-profit organization has not tools to directly control return on investment. Full responsibility for the management at the university depends on the maturity of management staff, which plays in the quality application also the basic role. Therefore in the quality application at University plays an important role not only the level of education, but also the organization arrangement that is dependent on experience and readiness of management.

The main parts of structure that creates quality assurance are designed in Figure 5, in the widest context including more necessary factors to reach good and powerful result. There are four main areas in quality management which are:

- Staff, which must be technically and pedagogically high-level, including friendly economic thinking,
- Education system, which must be transparent, with clear rules and expertly balanced,
- Facilities, which must provide access not only the theoretical but also practical training,
- Organization of processes in all sectors, including restrictions of unnecessary administrative.

Very experienced staff is irreplaceable. Science runs ahead, but has its foundations in the past. Therefore, requirements for management is constantly expanding and growing. This applies not only technical knowledge but also teaching skills, attitudes in the area of economic management and other areas. And here are the best school of practical experience that cannot be replaced theories. Therefore, filling leadership positions must be open to the widest possible range of candidates, to be selected real personality.

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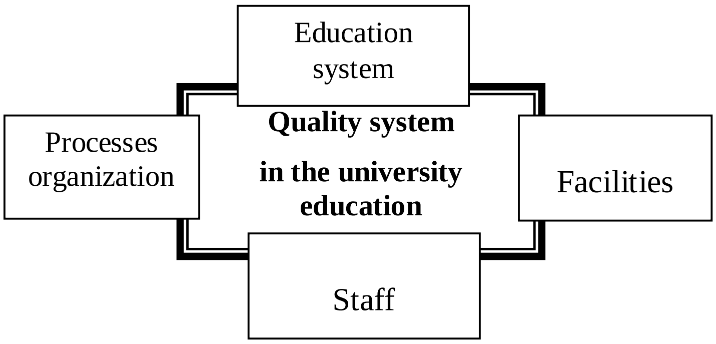

Figure 5. Basic structure of quality system in the education

Experience is a guarantee not only for management functions, but also for academic staff. This concerns not only technical knowledge, but also teacher training, which contains the knowledge of methodology, rhetoric, psychology, and also ideas about personal, financial decision making, etc. Then all that remains is to create a quality department. It initially may consist of only one experienced quality manager, which will generate documentation for the complete quality system.

Each quality system must be built for the particular conditions since the beginning. The rules and requirements for all four sectors must be defined (see Fig.5), and must be for them established assessment criteria. Where are the most frequent typical shortcomings in the universities? It may be insufficient training of teachers, lack of experience, also poor language skills etc. In the case of the educational system, it can be repetitive curriculum in various subjects, redundancy of subjects, missing subjects, non-actual curriculum etc. A major problem at universities in the area of labors is on the one hand, lack of equipment and on the other unused and multiple equipment. And all of this can be controlled and improved with a functioning system of quality.

One part of the quality system consists of quality organizational structure and its useful functioning. The second part consists acquisition, processing and utilization of data from the educational process. It is clear that both are absolutely essential and necessary for the establishment of an effective quality system. Establishing a system for data acquisition and their correct selection is a crucial part of the quality system. And here it is necessary to recall the main points of Deming's theory of quality, where excessive administration and lack of clear goals acts as a fatal disease.

One short example coming up from a survey, which was done directly with students at Brno University of Technology is demonstrated. Survey was done repeatedly over two years among approximately eighty students from the last year of Magister study program. The question was, what is your main criterion for assessing the quality of teaching in the course of your studies? Over 90% of the responses were distributed into three groups, with a frequency of 48%, 37% and 14% in the following order: level of lecturers and teachers, university facilities, the organization and content of teaching. The responses confirmed the fact indicated on Figure 5. Moreover, there is a factor "Process organization", which is fully in line competence of management and determines in quality system the level of efficiency. Here, it should be appreciated that the introduction of legislative and effective quality system at the university is absolutely only possible with the full support of management.

Each quality system must be formed from basic steps, like the house, and must be adapted to the specific conditions. And also every quality system must have a professional control that is fully engaged in this activity in close cooperation with management. The quality system at the Brno University of Technology, Faculty of Electronic and Electric Engineering is formed gradually, where the goal is to find optimized data from the each areas.

5. Conclusion

The rapid development requires not only talk about quality, but also to deal with quality. Many qualitative and quantitative changes in science occurred in recent decades. This produces new technical branches and increases the amount of information. Thereby it creates a major problem to control and manage such a large amount of information, often in areas that are highly specialized. Just like when were open markets in the world, it was necessary to establish uniform standards for quality control, it is also necessary to look for an effective quality control system in the university sector. It must be understood when the quality system is correctly applied, brings both process improvement and also increasing of their efficiency. It then delivers the satisfaction of all partners involved in the educational process, which also includes companies and institutions receiving students. These institutions must have a decisive role in determining the level of graduates, which together with the indicator number of employed students from a particular school, should be the decisive criterion for allocation of state subsidies. Not the number of students admitted, as it is often in reality.

Current status leads to uncontrolled activities towards the greatest number of publications, to obtain projects and other activities that are currently valued. Notwithstanding that the publication does not, and in many cases it is not, the real benefit in many cases also does not ensure return money. And then there is not time to update teaching and monitoring its quality. Some basic facts, aiming to evoke reflections on the introduction of a uniform system of quality in education are in this paper introduced. It outlines the main factors that affect the quality of the educational process, and subsequently for obtain data for management. Of course the quality system is the issue very broad and complex, which cannot be described in the short form.

After reading this article should be understood the importance of quality in practice, and start thinking about its meaning. Then you can just ask ourselves whether we want to improve something, or to remain in the “old” system. I am convinced that knowledge of the quality has for university teachers the same meaning as knowledge of psychology or methodology, as every person is part of a system of quality. Therefore, the quality knowledge should be included in the education of university teachers. Then we can regarded the quality of the educational process, not only in terms of learning, but also improve the overall efficiency, including technical and economic control of the University. This paper is not guidance on how to implement a quality system in higher education, but its aim is to highlight the importance of the area that is often overlooked, even though it may raise the level of education and also bring savings.

6. Acknowledgements

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Significantly Improved Student Progression Results by Means of Course Integration and Collaborative Pedagogy in the Degree Programmes of Electronics, Electrical Engineering and Automation Technology of the Helsinki Metropolia UAS.

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Abstract

The curricula of all the engineering degree programmes of the Helsinki Metropolia University of Applied Sciences went through a fundamental change in 2014. Most old programmes were merged and the pedagogy is based on collaborative teaching and learning. The studies of most engineering programmes are organized in modules of 15 ECTS credits (10 weeks). The modular structure facilitates cooperation between programmes and gives the students a much wider variety of choices in their study path. The degree programmes of Automation Technology and Electrical Engineering (tuition in Finnish) were merged and combined organizationally as well to the degree programme in Electronics (in English). It was decided that all the courses within the study modules in these programmes will be completely integrated and one study module thus consists of just one single course of 15 ECTS credits based on course integration and collaborative teaching between multiple members of academic staff as well as continuous assessment throughout the course leading to one single grade only. The goal was to improve the student progression since the current funding model of the Finnish UAS's is heavily based on it. The first results after the first semester reported here show that this model significantly improves the results and more than 93% of all the students in these degree programmes have passed all the courses in time compared to the relatively low values of 70% in 2013 and 50% in 2012.

Keywords: *Integration of studies, Collaborative teaching and learning, Continuous assessment*.

1. Introduction

All the engineering degree programmes in Helsinki Metropolia University of Applied Sciences went through a fundamental change in 2014. The total number of degree programmes was significantly reduced by merging the old degree programmes. Therefore all the curricula had to be renovated in spring 2014. It was decided by the pedagogical management board of the university that the new curricula are based on a modular structure and the pedagogy is based on collaborative teaching and learning [1].

The degree programme of Electrical Engineering and the degree programme of Automation Technology were merged in that process and the first students started their studies in the new degree programme of Electrical Engineering and Automation Technology (tuition in Finnish) in August 2014. The degree programme in Electronics (in English) is still independent since the student intake process is different in the English programmes. However its contents are heavily integrated to the Finnish degree programme and the study paths of the students studying electronics in either of the programmes are combined after the second or fourth semester (depending on the number of students selecting electronics as their major in the Finnish programme). The new curriculum of these degree programmes is linked to the curricula of other engineering degree programmes in order to offer efficiently multiple specialization options in the students' study path [2].

In Finland most of the funding of the Universities of Applied Sciences comes directly from the Finnish Ministry of Education. The level of this funding has been significantly reduced and the funding principles were totally

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changed for 2014. Previously the funding was based on the number of students as well as the number of graduates. Currently the funding is still based heavily on the number of graduates but no longer on the total number of students. Instead the funding is based on the number of students making more than 55 ECTS credits per study year of the 60 ECTS total (i.e. 91.7% of the total credits completed). Therefore the universities want to improve the student progression in order to make sure that the students make all the courses in time to fulfil the funding criteria. The results in that respect have been relatively poor in the past, since the studies in the engineering degree programmes has been rather flexible and therefore it has been possible for the students to leave some courses to be completed in the future semesters instead of completing all the courses in due time. The curricula of the engineering degree programmes in Metropolia have been previously based in small courses of 3 ECTS credits only and if the students have two of such courses a year pending, the funding criteria is not met. In the old programmes of Electrical Engineering, Automation Technology and Electronics the number of first year students fulfilling the funding criteria was even small than 50% in 2012. This number is however 10% higher compared to the mean level of all the engineering programmes in Metropolia. When the new funding principles were announced in 2012, many actions were taken within the old curriculum as well. The teaching staff was encouraged to use continuous assessment instead of the end exams, alternative resit options were given to the students etc. By these means the number of first year students fulfilling the criteria in these three programmes was raised above 70% in 2013.

Further improvement was still necessary and since the curricula had to be renovated in 2014, it was decided that all the courses in these programmes will be organized in larger entities of 15 ECTS credits based on collaborative teaching and learning and continuous assessment. Much focus was given as well to student tutoring in the courses. The students of the first intake studying according to the new principles have now completed the first semester of their studies and therefore it is now possible to compare their progression results to previous years.

2. Modular Curriculum

The modular structure of the curriculum is described in detail in [2]. The students have to complete altogether 240 ECTS credits to get the Bachelor of Engineering degree. The studies in most engineering programmes in Helsinki Metropolia UAS are organized in modules of 15 ECTS credits. The duration of studies is 4 years and each year of study consists of altogether 4 modules (i.e. 60 credits). In university level the minimum content of one single course is 5 credits and in many programmes one study module consists of three individual courses of 5 credits. In the three degree programmes covered in this paper however each module consists of just one single course of 15 ECTS credits and the duration of each module is 10 weeks. Thus the students have to complete just two consecutive courses per semester. Each course is organized by a larger number of professors and different subjects are integrated within the courses by common exercises, projects etc. Finally the students will have just one single grade of the whole module. There are three main reasons for this integration to larger course entities: 1) the members of staff have to cooperate and take into account other subjects when they plan their own teaching and as well organize common exercises and projects with each other, 2) the assessment of the courses is transparent and all the professors have to work based on the given specifications of continuous assessment and 3) the students may not leave one smaller topic/subject pending since by doing so they'll fail the whole package of 15 credits. The collaborative approach of 1) and 2) should improve the learning outcomes and those steps together with 3) should improve the student progression and raise the number of students fulfilling the funding criteria.

The yearly student intake to the new degree programme in Electrical Engineering and Automation Technology was 120 students in August 2014 (excluding the part time evening students) and 40 students to the English Degree Programme in Electronics. Further 40 students started in the Finnish programme in January 2015. Thus the total yearly intake is 200 students (and 50 part time evening students). The contents of the two degree programmes (Finnish and English) are exactly the same through the first two semesters. After the 2nd semester the students continue their studies based on their selected major; electrical power engineering, automation technology or electronics. The actual selection is done after the first half of the second semester, i.e. after the third study module. The contents of the second year are exactly the same for all the students within a major. If only a small number of students in the Finnish programme select electronics, their group is merged with the group of Electronics students in the English programme. This merger will take place in 2015, since only less than 20 students of the Finnish programme selected Electronics (selections in March 2015). Finally the total group of students is quite evenly divided to three majors approximately 60 students continuing their studies in each major. The number of dropouts has so far been 20 students.

After the second year of study the students may then select study modules quite freely. They have to complete altogether two study modules of their major, two internships of 15 ECTS (10 weeks), the Metropolia innovation project, two totally optional modules that the students may select from other programmes as well and finally they have to do complete their bachelor project / thesis.

3. Course Structure and Contents of the first Year of Study

The first year of study in the degree programme in Electrical Engineering and Automation Technology (in Finnish) and as well the degree programme in Electronics (in English) consists of the modules and courses listed in Table1. The contents of each course or module are listed in the table as well.

Table 1. Contents of the first year of study in the degree programme in Electrical Engineering and Automation Technology as well as in the degree programme in Electronics

Module number	ECTS credits	Name of the course / module	Course contents
Module 1	15	**Orientation to Engineering Studies**	1. expressions, equations and functions 2. quantities and units 3. graphical chart 4. communications skills for technology 5. oral and written reporting and communication 6. introduction to programming 7. learning and study skills 8. introduction to current topics in the field 9. key guidelines of higher education studies 10. Metropolia as a study environment 11. electrical safety at work
Module 2	15	**Orientation to Electronics and Electrical Engineering**	1. physics related to electronics and electrical eng. 2. DC circuits 3. basics of Analog Electronics 4. basics of Digital Electronics 5. vectors, matrices and complex numbers 6. introductory project
Module 3	15	**Orientation to Electrical Power Engineering and Automation**	1. elementary differential and integral calculus 2. concepts of a derivative and an integral 3. mechanics 4. introduction to automation 5. introducton to electrical power engineering 6. English language 7. AC circuits
Module 4	15	**Project in Electrical Engineering and Automation Technology**	1. applications of differential calculus 2. magnetism 3. computer aided design 4. communication and documentation in English 5. design project
Total	60		

Each of the four modules listed in the table are thus organized as one single course of 15 ECTS credits. The student will have just one single grade of the whole course. All the contents listed in the table are integrated within the course and there is always multiple members of staff teaching the topics within a course. The courses are consecutive, i.e. module 1 lasts first 10 weeks of the first semester, module 2 the last 10 weeks of the first semester etc.

When these courses were organized for the first time in autumn semester 2014 the 160 students were divided to four groups of 40 students (three groups taught in Finnish, one in English). Unfortunately these groups were divided between two campuses, since the old degree programme of Automation Technology is located on another campus 15 km outside Helsinki center where the main campus is located. This problem will be solved finally

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when the new Metropolia campuses will be constructed by 2018 and all the required lab facilities and staff will be at the same campus.

Five members of academic staff organized the teaching for each group. Each group was given a certain specific time related resources to organize the teaching and in most groups these resources were evenly divided to teachers. Each teacher had his/her share of the content and the weekly schedule was split quite evenly between different teachers teaching that group. The teachers were heavily encouraged to create common exercises, projects and other tasks for the students to integrate the topics together. However, in the first round the teachers were not heavily forced, since all the members of staff were needed and therefore the system was quite flexible. The teachers did have to cooperate at least through the continuous assessment system and most teachers did create common learning tasks for the students already during the first realizations of the courses.

Each group of the first year students were given a classroom of their own. If other facilities were needed (i.e. lab facilities or computer classes), the teachers had to reserve those separately. The study schedule was organized in a way that the students had 5-6 hours of teaching each day from Monday to Thursday ad 3 hours on Friday. The daily hours were scheduled from 8 am to 10.30 am and then again from 1 pm to 3.30 pm. The time in between was reserved for lunch as well as independent student work to complete all the weekly tasks given by the teachers.

In all the parallel groups there were five teachers organizing the first module: a mathematics teacher (content 1), a physics teacher (contents 2 and 3), a teacher in Finnish (or English) communication (contents 4 and 5), an expert of professional studies (contents 6 and 11) and finally a teacher organizing the introduction to engineering part specified by the CDIO pedagogy [3] that is as well followed in all the engineering degree programmes in the university (contents 7,8,9 and 10). In all the groups at least all the contents of communication skills were connected to reports and documents of other topics. Much cooperation took place as well between the mathematics and physics contents, but it was known already before the start, that this module is definitely the one with least cooperation opportunities between the contents.

The contents of module 2 were split similarly between specialists in physics (content 1), electronics (3 and 4), circuit theory (content 2), mathematics (content 5) as well as a specialist organizing the project (content 6). The actual introductory project (as well a CDIO requirement [3]) was slightly different for different groups depending on the responsible teacher. This module offered already much more cooperation possibilities compared to module 1 and in future modules it is still much easier. For example in module 4 the actual design project (content 5) is designed by the CAD tools (content 3) and most project documents and most of the meetings are held in English (content 4). In future years most modules will be much more focused on certain engineering topics and there'll be fewer teachers involved, and required mathematics and physics contents may be applied directly to the topic in focus.

4. Continuous Course Assessment and Student Tutoring

The teachers involved were given relative freedom in organizing the teaching. There were however some limitations. First of all the courses had to be based on continuous assessment meaning that there should be weekly tasks and weekly feedback for the students, and end exams were totally banned. Other types of smaller exams throughout the course were allowed, as long as a student does not fail the whole large course by failing one single smaller exam.

The student tutoring during the courses was as well emphasized. Each parallel student group of 40 students was divided to 5 subgroups of 8 students. Each of the five teachers was nominated as a tutor of one subgroup. The task of the tutor was to meet with his/her subgroup weekly, follow the progression/results/behaviour of the students in his/her subgroup as well as to give and receive feedback from the students and forward this information to his/her colleagues if necessary.

The teachers were able to select their assessment method and procedure freely within given limits. Different approaches were encouraged and the best practices will be chosen as common processes for the students staring in August 2015. One of the teachers in each group was selected as the responsible teacher organizing the assessment and other practices. Different teachers have had this responsibility and even more teachers have been involved in different assessment processes. It has to be admitted that allowing different approaches has made it quite tedious for some teachers, when it has been necessary to adjust to a new method all over again and again.

Organized feedback has not yet been collected on the different assessment approaches, but most groups in the fourth module (or the second module for students that started in January 2015) have selected the procedure which is very simple. In that method all the five teachers give the students weekly tasks (homework assignments, lab exercises, project reports etc.). Each teacher gives such tasks eight times during the course, and thus the total number of tasks is 40. These tasks are assessed as pass/fail before the following week's Wednesday and the students will have a feedback of the tasks in the meeting of their subgroup in the end of the week. If students complete more than 36 of these tasks, they'll pass the whole course. The actual grade is then set by smaller exams or other tasks assessed by points. Each teacher organizes small exams and other tasks to be assessed by points throughout the course and gives a maximum of 20 points based on these tasks. The grade is finally set by the points collected from these tasks. It is already clearly seen that using these methods of continuous assessment the students work actively throughout the course instead of just focusing on the end exam. Nearly all students complete the courses in time thus improving the student progression results.

Also the student learning outcomes have to be measured, analysed and compared to previous level in the future. We do already however believe, that the student learning outcomes are at least at the same level as before and all the students would as well be able to pass end exams comparable to ones of the previous year, but that has to be further investigated through tests.

5. Student Progression Results

By the end of 2014 the first students in the new degree programmes had completed two modules of 15 ECTS credits. All the results were fed to the university database by mid-January. The right-most posts in Figure 1. show the distribution of the student credits after the first semester in the degree programme in Electrical Engineering and Automation (in Finnish). As it may be seen, all the students have either 30, 15 or no credits at all after the first semester. These graphs do not include the students of the degree programme in Electronics (in English). The corresponding graph of that programme is similar, but some students have as well 20 or 35 credits, since some students have completed as well courses of Finnish languages already during the first semester.

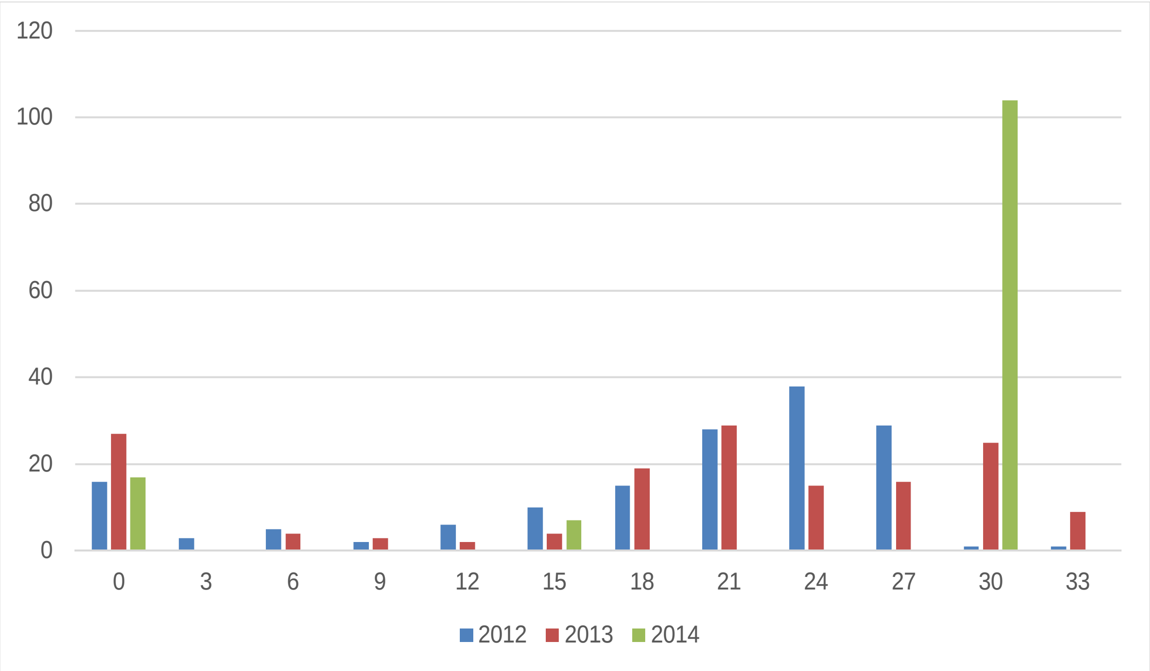

Figure 1. The credit distribution of the students of the degree programme in Electrical Engineering and Automation after the first semester in 2014 compared to two previous years (results of two old programmes combined). The number of credits in x-axis and the number of students in y-axis.

The two other posts in Figure 1 show the corresponding distribution (first semester) of years 2012 and 2013, when the studies were organized in 3 credit courses. These numbers include the students of both two old Finnish degree programmes before the merger (Automation Technology / Electrical Engineering). Some students have completed even 33 credits, which may be done by passing some optional courses during the first year. In 2012 the average is 21 credits / semester and in 2013 the average is 23 credits / semester. In 2014 the average is 29 credits / semester. The students who had completed no credits at all were omitted from these average calculations, since they had not started the studies at all or had quit during the first weeks. The corresponding average values for the degree programme of Electronics are 11 credits in 2012, 23 credits in 2013 and 32.5 credits in 2014. These values are not totally realistic in all respects, since after having a closer look at the student records, it seems that some course

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results are still pending for some reason still in late January (the data for 2012 and 2013 is collected in January 31st). Therefore in the coming analyses in Figures 2 and 3 the data of the first semester in 2014 is compared to the data of the first two semesters (i.e. credits after a whole year analyzed in late July when all courses are definitely in the database) of the student intakes of 2012 and 2013.

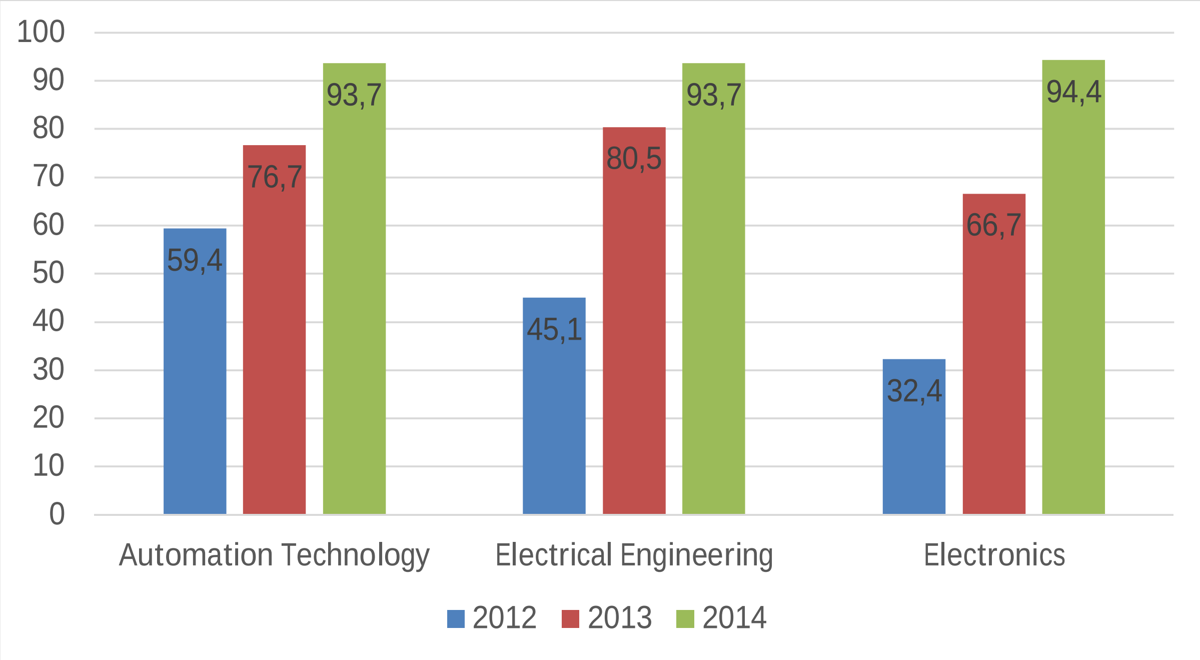

Figure 2. The percentage of students in three different degree programmes completing more than 55 credits a year in 2012 and 2013 compared to the percentage of students completing more than 27,5 credits in the first semester in 2014 (55 credits a year being the funding limit in Finnish UASs).

Figure 2 shows the percentage of first year students completing more than 55 credits in first two semesters in 2012 and 2013 and the percentage of the first year students completing more than 27,5 credits in the first semester of 2014. The limit in this analysis was set deliberately to the level of 55 credits per year since that is the funding limit of the universities of applied sciences in Finland. As stated above comparing the whole year of 2012 and 2013 gives more reliable results compared to the first semester of 2014 even though now the results of 2014 may be somewhat pessimistic compared to the previous years for the same reasons. The students completing less than 30 credits a year are omitted from the analyses of years 2012 and 2013 since such students may have changed the degree programme after the first semester, gone to do their military service or just quit their studies. As before the students completing no credits in 2014 are omitted for same reasons.

It may be directly seen that the impact of the new curriculum on the student progression is huge. These results improve the funding of these programmes significantly. It may as well be seen that when the new funding principles were announced in 2012, the results were already strongly improved from 2012 to 2013. Further improvement however would not have been possible without a total renovation of the pedagogical model.

In Figure 2. the results of the degree programmes of Automation Technology and Electrical Engineering are deliberately the same for 2014 since then the programmes were merged (this applies as well to Figure 3.). The large differences between the results of the degree programmes in 2012 have to be further investigated. One of the possible reasons for the poor results in the degree programme in Electronics compared to the other programmes is that the Finnish government supports economically the Finnish students during their studies when the non-Finns usually have to work to support themselves.

Figure 3. shows the percentage of studies completed in different degree programmes after the two first semesters in 2012 and 2013 and after the first semester in 2014. The total offering for two semesters here is 60 credits and 30 credits for one semester. The high number in 2014 in the degree programme in Electronics is achieved by foreign students completing optional courses in Finnish language in the first semester. These values are calculated by comparing the student credit average to the total offering.

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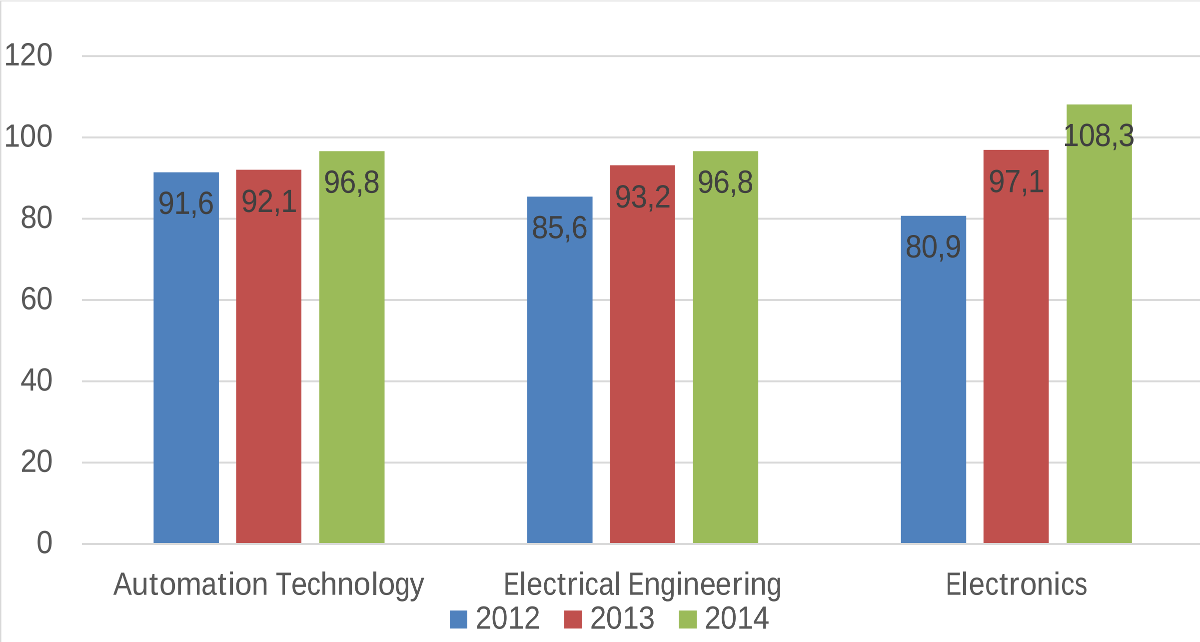

Figure 3. The percentage of studies completed in different degree programmes after the two first semesters in 2012 and 2013 and after the first semester in 2014.

It may be seen that the results of 2012 and 2013 are surprisingly high compared to the corresponding results in Figure 2, where the percentage of students reaching the funding limit is analysed. The reason for this surprising result is that many students have completed a relatively large number of credits during the first year still however not reaching the funding limit. For example the raise on only 0.5% of the credit average from 2012 to 2013 in the degree programme in Automation Technology did raise the number of students reaching the funding limit by 17.3%. The same phenomenon may be seen in all the degree programmes. Thus if only the funding criteria is taken into account, the results have been greatly improved already from 2012 to 2013 and the new pedagogical approach and curricular structure seem to maximize the results.

6. Conclusion and Future Plans

According to the analysis described here the student progression results have been greatly improved in the degree programme in Electrical Engineering and Automation Technology and in the degree programme in Electronics of Helsinki Metropolia University of Applied Sciences. This is achieved by using a modular curriculum and integrating the study contents to larger course entities when the students finally have to complete all the courses in time to proceed in their studies. Much emphasis is put to continuous assessment during the courses, student tutoring and feedback as well as increased cooperation between the members of staff organizing the courses.

The first results after the first semester are described in this paper. Further analysis will be done after the second semester. The learning outcomes of the students has to be analysed in detail and compared to the learning outcomes of the previous years as well. Organized student and teacher feedback has to be collected and analysed. The major feedback survey in Helsinki Metropolia UAS is organized during the third semester, but minor feedback surveys may be organized before that.

The different assessments have to be compared as well in spring 2014 and the standard method should be selected for students starting in August 2015. The results have to be as well compared to other degree programmes of the university, since the modular approach has been introduced in other programmes as well.

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An Evaluation of Three Freshman Experience Classes

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Abstract

The strong job market in Engineering and Computing is attracting more students to these majors but shortages at crisis levels are still widely projected. Freshman retention is an important factor affecting graduation rates and number of degrees granted [1]. Most Universities use freshman experience classes/seminars (and other methods [2]-[4]) to provide incoming students with the skills and encourage behaviors that will help them succeed in these demanding majors. In this paper we discuss and evaluate three freshman experience classes: a university-wide class during 2007-2010 and its School-based successors in the School of Engineering and Computer Science and the School of Management during 2011-2014. We report on approached used, retention rates, evaluations and lessons learned.

Keywords: *Freshman retention, Freshman experience classes, Retention rates*

1. Introduction

Up to and including the 2010-11 academic year, the University of Texas at Dallas required its incoming freshmen university-wide to take RHET 1101 Oral Communication/Critical Thinking (1 semester credit hour). The class focused on adapting to college, personal management skills, motivation, work habits, communication and social skills, critical thinking and planning. It could be used towards the free elective requirements in a student's degree plan. RHET 1101 was delivered in small sections of up to 19 students; the instructors included many faculty members earlier on but by the mid-2000s it was taught mainly by university staff (mostly academic advisors).

In the School of Engineering and Computer Science, efforts to introduce an “Introduction to Engineering and Computer Science “ class date back to at least 2005. The initial efforts included a summer head-start program for incoming freshmen that served as a vehicle for trying out ideas for a freshman experience class; it included a project-based class in which instructors from the student organizations led freshmen in team projects like programming robots to follow a black line and race through a maze. Requiring such a class for all freshmen met with significant opposition from faculty who argued that there was no room in the curriculum for such a class and questioned its value. The closest to a freshman experience class was EE 1202, a laboratory class that introduced students to laboratory procedures, engineering measurements, simple circuits. The first headway was made with the proposal for a new program in Mechanical Engineering which was submitted with an “Introduction to Mechanical Engineering class” in its degree requirements and prior to the hiring of faculty for the new program. The new degree program started in Fall 2008 with a three credit hour “Introduction to Mechanical Engineering class” that was immediately split into a two class sequence to provide contact with the Mechanical Engineering majors through their

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first year (during which they enrolled mostly in preparatory Science and Mathematics classes offered by other Departments).

Finally in Fall 2011, ECS 1200 – Introduction to Engineering and Computer Science (2 credit hours) was introduced as a degree requirement for all majors in the School. It incorporated several best practices [5] including Living Learning communities, Project-based learning, block scheduling. At the same time, the rest of the University abandoned RHET 1101 in favor of a new UNIV 1010 requirement for the First-Time-In-College (FTIC) students in its other schools. In this paper we discuss and evaluate the last four years of the RHET 1101 class and the first four years of the ECS 1200 and UNIV 1010 university requirement (in the School of Engineering and School of Management respectively) by reporting on approached used, retention rates, evaluations and lessons learned.

2. RHET 1101 from Fall 2007 to Fall 2010

The University of Texas at Dallas has had a rather unusual history. It started as a Graduate Research Center in the 1960s focusing on Space Sciences. Graduate programs were added first and then upper-level only undergraduate programs were introduced to provide Bachelor degree options for students enrolled in local community colleges. Continuing on this track, the University admitted its first freshman class for Fall 1992. The School of Engineering and Computer Science was established in 1986 by moving an existing Computer Science Program from the Department of Mathematics to the new school and starting a brand new Electrical Engineering program. The School has experienced tremendous growth going from an initial enrollment of about 600 students to over 5,700 in Fall 2014 ranking second in size to the School of Management (with an enrollment of over 7,000).

To serve its incoming freshmen, the University introduced RHET 1101 Oral Communication/Critical Thinking, which all students entering from High School had to take in their first year and preferably during their first semester in attendance. This small group class focused on the most important aspects of adapting to college e.g. personal management, motivation, academic skills and work habits, communication skills and social relationships, critical thinking and creative planning).

During the four years period 2007-2010, the RHET 1101 class was delivered mostly in the Fall semester (with 60-70 sections of it in Fall while only 2-3 sections in the following Spring). Class size was capped at 19 to improve student involvement in discussions and activities. Course content was set centrally for the most part with instructors given flexibility on what to do for 2 to 3 weeks out of the semester. Although students tended to enroll in sections with instructors associated with the school of their major,

Most sections had enrollments from across the university. Course evaluation scores spread over a very wide range (from lows of 15% to highs over 90% satisfaction with the class) with the ratings remaining pretty consistent for instructors over the years. Table 1 shows the freshman retention rates for the University going back to the freshman class of 2007.

Table 1. Freshman retention rates at the University level.

Year	UTD-retain
2007	83%
2008	84%
2009	85%
2010	83%
2011	85%
2012	89%
2013	87%

3. The Evolution of the Freshman Experience Course in JSOM

The Jindal School of Management (JSOM) is the largest School at the University of Texas at Dallas. RHET 1101 Oral Communication/Critical Thinking was the original freshmen experience course, based on the transition from high school to college, and taught originally by faculty, but over the years was ultimately primarily by advisors and staff, with the help of upper level students. The curriculum was managed through the office of Undergraduate Education. The course was one credit hour and was graded. Several sections of the course were taught by JSOM faculty and staff, and though students were encouraged to register in those sections, the students from various majors were mixed, and content was not major specific.

For incoming freshmen in fall 2011, the new course, UNIV 1010 was instituted, and was taught primarily by deans, associate deans, and other faculty, with fewer staff and advisors involved. The course was zero credit hours, and graded as credit/no credit. The goal was to enroll freshmen in the sections taught by instructors from their major areas, but due to schedule conflicts, this did not always work.

In JSOM, all of the sections were taught by the one faculty member, for consistency. The course required attendance at university level lectures, small section sessions, and online learning modules. Unfortunately, the class sections were not purely JSOM students – and JSOM students were therefore place in sections for other majors. The result was that though major-related content was provided in the courses, the composition of students in the class sections did not match the content provided. The retention rate for JSOM freshmen was 77.14%, certainly disappointing, but not surprising, since many students were never exposed to the course material designed to introduce them to their major.

Overall for the university, the course curriculum had improved by adding academic content, but we lacked consistency. Students were surveyed and the overwhelming response was that the specific course content that most benefitted the students was both related to their major and to possible career paths. Since some sections of the course were still taught under the old model by staff and advisors, those students were not exposed to any of that content. The credit/no credit grading did not motivate students to work or participate in class. Given the inconsistencies, it was decided that one course and one hour per week were not enough to accomplish our goals for freshmen.

Therefore, given the inconsistencies and lack of necessary contact hours to accomplish the goals for the freshman experience, the model changed again for fall 2012. The new requirement became two courses:

- UNIV1010
  - Taught by an upper classman
  - Content centered on the transition to college
  - Supervised by the Office of Undergraduate Education
  - Zero credit hours
  - Credit/No credit
- A school based course 1100
  - Taught by faculty
  - Content centered on academic area and careers
  - 1 credit hour
  - Graded
  - 20% of grade based on passing UNIV 1010 (all or nothing 20 or 0 points)

In 2012, all JSOM sections of the 1100 course were taught by a single faculty member. The curriculum remained the same as in the 2011 UNIV1010 course, but this time all JSOM students were enrolled in the JSOM 1100 course along with UNIV 1010 sections taught by JSOM students. The faculty and student instructors met regularly. The switch to a graded format helped engage the students. Retention increased to 84.9%. Students were pleased with the major and career curriculum.

In 2013, the number of JSOM freshman increased 70%, and the instruction changed again. The JSOM sections of the 1100 course were taught by 2 instructors, and the curriculum was changed to include

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outside speakers, more writing, and a more formal procedure for the group project, as the focus turned more toward an introduction to business than an introduction to the majors. The student instructors of UNIV1010 were less engaged with the faculty than in the prior year. Retention decreased to 81%.

In 2013 and 2014, the university worked on improving the 1100 class curriculums within the schools, since there were many different approaches across the schools. At the same time, the university was designing a new core curriculum that would satisfy the new state requirements. This included reclassifying courses, rewriting course descriptions, and defining assessment plans. The committee determined that the most effective way to assess the core would be to begin with a baseline measure for incoming freshmen across the core objectives, then to assess again upon core curriculum completion. We decided that the most appropriate venue for the baseline assessment would be UNIV1010.

During fall 2014, students were being assessed within UNIV 1010 and ECS 1200. Once we have those results, we can better adjust future course content. Going forward to 2015, the plan is to utilize UNIV1010 as an instrument for student academic success and introduction to the university.

Table 2. Freshman retention rates in the School of Management.

Cohort	Freshman Retention Rate
FTIC-2011	77.14%
FTIC-2012	84.92%
FTIC-2013	81.05%

4. The “Introduction to Engineering and Computer Science” Class

ECS 1200 – Introduction to Engineering and Computer Science was introduced as a degree requirement for all ECS majors in Fall 2011 after several years of trying to introduce such a class to help retention. In Fall 2011, ECS 1200 was taught as a (1-2) lecture–lab hour class with a total of 3 contact hours per week and two credit hours. The university-wide UNIV 1010 graduation requirement was satisfied through ECS 1200 for majors in the School of Engineering and Computer Science by including some of the content from UNIV 1010 in ECS 1200 and creating a parallel lecture series within the School. Besides the FTIC Freshmen with ECS majors, the class enrolled over 200 new transfer students and students that changed major as it was felt that they would also benefit from such a class. The class was delivers in 9 section of about 75 with six instructors. The large size of the sections was dictated by the (un-)availability of instructors. The class included a Living Learning Community section, a section with students sharing at least two classes, Peer-Led Team Learning (PLTL) support and peer mentors. ECS 1200 had large variations in grading among sections. The need for common attendance and grading policies and the connection to UNIV 1010 turned out to be significant issues that were never fully resolved.

In Fall 2012, both ECS 1200 and UNIV 1010 dropped the lecture series. Also bypass conditions were developed to replace the ECS 1200 degree requirement with upper level hours in the major for non-FTIC students and enrollment in ECS 1200 was limited to FTIC freshmen. Only two of the six instructors from

2011 were involved with the class in Fall 2012. The class met in two 75-minute sessions one of which was treated as a separate "lab" that was delivered mostly by advisors and upper-classmen interns (we had 15 lecture sections staffed mostly with senior lectures provided by the Department and 22 lab sections). Grades from the two parts had to be combined but the grading was more uniform grading across sections.

Demands for more control by the instructors provided by the Departments led to further structural changes for Fall 2013. Instructors handled 2 of 3 50-minute meetings a week with the remaining meeting handled by advisors/interns. This trend continued in Fall 2014 with three of the four Departments in the School taking full control of the class; ECS 1200 was delivered in sections scheduled by the Departments and "strongly recommended" for their own majors.

Table 3 shows freshman retention in the school and university for the FTIC cohorts in the School of Engineering and Computer Science since 2007.

Table 3. Freshman retention rates for the School of Engineering and Computer Science

School	FTIC Year	Retain-School	Retain-University
ECS	2007	74.4%	87.7%
ECS	2008	73.3%	86.6%
ECS	2009	71.4%	86.00%
ECS	2010	68.1%	81.50%
ECS	2011	72.4%	84.80%
ECS	2012	76.4%	86.40%
ECS	2013	76.7%	85.60%

In general, students liked the instructors more than the class itself (questioning its value was a very common comment). Similar classes in other schools were better received. ECS 1200 experienced very high rates of instructor turnover and that likely affected ratings (many of the instructors were brand-new hires) Control over grading was a major issue with both tenure-track faculty and lecturers and was likely linked to teaching evaluations [6], [7]. The mandatory attendance policy for ECS 1200 was the main reason for high failure rates; but it was balanced by grade inflation for the group that attended. An analysis of the transcripts of students that were not retained identified two main groups: one group consists of students that did not adjust to the university well and did poorly in most/all of their classes (most left the university); a second group consists of students that were not well-prepared and had difficulties with gateway classes like Calculus (with Programming classes a close second) – many of them changed to a less demanding major.

5. Conclusions

With the introduction of ECS 1200 in Fall 2011, freshman retention in the School of Engineering and Computer Science improved each year with significant improvements of at least four percentage points the first two years and a marginal improvement for the 2013 class. Retention at the University level was significantly higher as one would expect [4], [5]. This improvement followed a few years of declining freshman retention (with RHET 1101) but it is likely that other factors are involved as well (since retention was at higher levels in the early 2000s. In the School of Management, the major improvement resulting from the addition of the 1100 class in Fall 2012 is worth noting.

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For Fall 2015, the focus of the freshman retention efforts will shift to the Schools; each school will have its own 1100 class which will incorporate the UNIV 1010 content by meeting on a (1-1) pattern (two 50-minute sessions a week ECS 1200 will be split into a School-wide ECS 1100 class that will operate similarly to the 1100 classes in the other schools and an “Introduction to the Major” class administered by each Department. One can view this as a university-wide return to a RHET 1100 class with double the contact hours.

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Changes and Challenges in Engineering and Computer Sciences Education- Guidelines to Treat Wide Themes for Beginners

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Abstract

This paper explains thematic approach formulation looking for beginners´ context at Engineering and Computer Sciences courses. First task is to present an introductory text for the students. The text shows how wide themes, titled thematic, wed with Object Oriented knowledge modeling tool to achieve the thematic formulation at first glance. The paper illustrates a practical example of introductory text in the Environmental Engineering field of knowledge. After this, it is presented a case example of a Numerical Analysis teaching topic under, both, traditional discipline oriented approach and thematic oriented approach. Conclusion enhances it is possible to implement thematic oriented view also in very traditional discipline oriented curriculum. The proposal challenges teachers and students because it effectively changes engineering education towards new curricular approaches. The ´change´ is to treat knowledge as a wide theme at first glance. The ´challenge´ is to understand this concerns a paradigm shift, adequate to deal with educational demands at globalization times including technological areas.

Keywords: *Thematic Oriented Approach, Object Oriented Tool,Thematic Introduction .*

1. Introduction

The present paper discusses about new educational concepts which are useful in globalization times. They are times of increasing complexity in terms of engineering and computer sciences projects. The present paper author unifies two proposals (Complex Approach and Object Oriented knowledge modelling) enhancing how Engineering and Computer Sciences courses can implement complex thought ideas in terms of technological education since beginners' level. The author formulation is titled Thematic, Integrative, or even, Wide Theme in terms of knowledge modelling approach. A practical example will be explained, step by step, considering Thematic approach implementation in a traditional discipline oriented curriculum. They are no limitations about thematic approach practical implementation. The proposed example enhances it is always possible to implement the thematic proposal right now, even without other curricular modifications. Conclusion points out combination of Complex Though approach with Object Oriented knowledge modelling tool approach under thematic vision can effectively be implemented since beginners' level with positive pedagogic results.

2. What is Thematic Approach formulation? Advantages from Wide Themes vision

A terminology about thematic approach can be useful because it is coming popular on the last years under different names. Thematic approach concerns also to Project approach if project is considered as open models where it is possible to unify practical implementable and intangible (social, ecological, etc) topics, all together, influencing project solution. This approach can also be titled integrative view because of its synthesis character, [1]-[2]. Two authors, from different countries, have proposed quite at same time, the theoretical formulation for thematic approach. Edgar Morin, French philosopher has proposed the "Complex Thought" approach for knowledge treatment, [3]. Kristen Nygaard, Norwegian Mathematical and Informatics researcher has proposed the "Object Oriented" approach for knowledge modelling. The Object Oriented approach is applied to informatics knowledge systems modelling . The present paper author identifies Morin and Nygaard proposals as useful to all levels of education and shares her experience with those mentioned guidelines at class room activities at beginners' level. On this direction, thematic approach formulation, considering an academic course context, is a pedagogic proposal which refers to the implementation of wide themes as the knowledge axis structure using the Morin principles of complex thought combined with Nygaard knowledge modelling tool, [4].

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2.1. Advantages from Wide Themes vision

Wide themes refer to the called ´real world´ vision. Under this focus knowledge embeds, for example, social, economic, ecological, and technological aspects, all together. A global vision weds with local regional demands, which increases students' motivation contributing to create relevance or called by Morin, pertinence, and integration, two pedagogic parameters.

- Relevance of knowledge creation. This expression derived by Edgar Morin [3], represents a first advantage of wide themes presentation to students at first glance. It means student will learn well when he/her is motivated by the context of study (broad theme). Morin says, in his work about complex approach, what is associated with its wide context is more relevant, or pertinent following Morin term, to learn than isolated theoretical or without practical and direct necessity issues.
- Integration of knowledge creation. This directive offers possibility to save energy looking for project themes, at first glance, instead of isolated technical issues. Project approach is in accordance with Abet Criteria 2000. [5].

3. How to implement Wide Themes at Beginners' level?

Wide themes usually appear late at curricular structure, under disciplines titled Engineering Project or Information Systems Project, and so on. Those disciplines are typical located at master level and they depend of basic knowledge including softwares and computer numerical data analysis, for example. However, wide themes can be treated since beginners' level. How can it be done?
What is really important at initial moment? It refers to the first class of the first year at university. An open discussion will point out some wide theme of study. It is expected to discuss about a theme concerning the student specific career (some Engineering or Computer Science one). At the first class day, of course, it is impossible to implement all possible aspects emerged from a theme context. In addition, it is considered not usual to create and list problems that are not to be solved immediately concerning technological teaching/learning environment. Because of this, it is perceptible wide themes approach changes educational paradigm from technical focused to integrative one. It represents a change and a challenge. It invites people to follow another logic. Thematic approach, focused in wide themes vision, changes objectivity to somehow not implementable aspects but pertinent for the theme discussion. It is important, at first glance, to discuss open way, all possible aspects about the theme, without boundaries. It is not to worry about the possible or impossible solutions but to have a list of problems to solve in a future perspective, under a sequential line with increasing difficulty projects.

4. Wide Themes Pedagogic Proposal in Some Steps

Wide themes approach is still new concerning beginners' level in many curriculum of engineering and computer sciences undergraduate courses. The theme or project approach is implemented in some universities all over the world, [1],[4],[6],[7]. The author experience on this subject has occurred in an undergraduate course under a traditional curriculum structure. It means to say the theme approach boundary concerns an introductory discipline to teach computer sciences programming for all Engineering and also for Computer Sciences and Information Systems careers. This observation points out it is possible to implement this approach everywhere, in different educational contexts and curriculums. It will be suggested how to treat this pedagogic approach with students, in four steps, as follows.

4.1. Step one - Introductory Pedagogic Method Explanation

It is important to conceptualize the adopted pedagogic method. The most important directive to present to students is the integrative vision in education. This is relevant because it changes the traditional way to treat knowledge, as well as evaluation, and other pedagogic aspects. People must understand what is going on. This previous discussion also provides comprehension of method advantages. Some additional aspects to be explained are: knowledge approach (wide theme vision) and its foundation using Object Oriented knowledge modelling tool support; the first problem approach (principle of abstraction); the evaluation spirit under project approach (several dimensions of evaluation outer of traditional written evaluation).

4.2. Step two - Explanation about Knowledge Approach under Wide Theme Vision

It must to be clear for the students that this approach focus, at first glance, is the comprehension of the whole and not to the concrete implementation of practical problems. Students can bring ideas and suggestions of problems, independent from their implementation viability. Curiosity and not obvious aspects can be included in the wide theme discussion without censure. Students can explore, without restrictions, all kinds of information support like internet, newspapers, TV videos, cinema and so on. It arrives the moment to be explained to the students about a tool support to help to model such kind of problems which is expected to have increase difficulty versions, as times and course goes by. The teacher can explain about the advantages of using a knowledge modelling tool support to lead since the initial until advanced knowledge level. At this time, it is presented the principles of Object Oriented knowledge modelling tool for participants. Object- Oriented knowledge modelling tool is useful, independent from computer system implementation, to create adequate knowledge structures in easy and secure way considering vertical and horizontal expansion of knowledge categories, as projects increase complexity, [8]-[9].

4.3. Step three – Discussion about First Problem Approach under Wide Theme Vision

Wide theme vision brings a large range of problems with different levels of difficulty to solve. Some of those problems can be open problems referring to not, yet, have a practical solution. And how it is possible to begin to work if, at beginners' level, students do not still have technical skills to solve those different proposed problems? The answer is to clearly explain, knowledge is to be treated as projects concerning a process of sequential increasing difficulty projects, and not as an individual event. In this case, the first project abstracts, at maximum level, the reality and focus a very simple technical aspect. At same time, it will be understood the initial focus must be to the pedagogic method together with the technical aspects concerning the little project which will be developed, tested and solved. This way, student will not be frustrated to solve some easy operation like a sum to solve the first problem from an initial project belonging to a wide theme.

4.4. Step four - Discussion about Contents Evaluation Method under Wide Theme Vision

It arrives the moment to discuss how this pedagogic approach affects classroom pedagogic activities? To discuss about contents evaluation is important for students comprehension of the pedagogic method. Usually at practical engineering education context, written evaluation is a very popular evaluation method. Sometimes it combines some written works with written evaluation to arrive to the final and expected student score. The reality is affected by the wide theme vision because it transforms event focus towards process evaluation focus. Evaluation method now must create a combination of different kinds of evaluation parameters. But, if it is to follow the traditional written evaluation method, it is also possible to create an open evaluation vision under this traditional evaluation method, [10]. They are infinite way to arrive, somehow, to the spirit of integrative educational vision. It is important to not hurt the previous state of the art relative to each specific context or curriculum organization. To develop a new educational culture, a step by step implemented action is much more feasible than to impose a revolutionary one.

5. A Practical Example of Wide Theme Introduction - the Climate Study

The concrete experience with Climate study theme refers to the Environmental and Sanitary Engineering Course, as well as Computer Sciences and Information Systems undergraduate courses teaching. Discipline time duration was respectively 54 and 108 class hours. The wide theme came from Environmental Engineering course and the complex knowledge tool support (Object –Oriented tool) came from Computer Sciences courses. The pedagogic experience deals with an Introductory Computer Programming Discipline, for both courses. Climate Study theme introduction will be divided in four suggested tasks, as follows.

5.1. Task One- Introductory Method Explanation for Students

Table 1 illustrates some aspects of the formal presentation of the pedagogic method to the students. Climate study is one example. Students can bring other parallel themes of interest. Different themes can be developed parallel enhancing common math and technical aspects.

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Table 1. A Practical Wide Theme Context

1.Theme	Climate Study
2.Disciplines(introductory level)	Computer Programming / Eng. Project/ …
3.Courses	Environmental and Sanitary Eng./ Computer Sciences/ Information Systems/ …
4.Knowledge Modelling Tool	Object Oriented Tool
5.Teaching Methodology	Thematic Vision in Education
6.Theme Life Cycle	A semester (in the specific example)

This initial discussion is specific in accordance with each context (for example, sanitary engineering course, or computer sciences course; Structured Pascal, or Object-Oriented modelling tool, and so on). Issue 5 is the most important to discuss with students. They must walk together with teacher on those new educational ways.

5.2. Task Two- Example of Data Research about Climate Study Theme

Now is it time to organize information about the theme of study (Climate Study theme). A summary of information are presented, random way. Students have collected and brought to the classroom those contents contributing to theme initial discussion. What is relevant to observe is how wide and open context can be associated with them.

- **Practical Climate Study Applications:** Aircraft Flights, Tourism, Agriculture, Ocean Engineering, Hydro- Meteorology (hydraulic studies, hydroelectric, floods), Fish Engineering, Industry and Commerce, etc.
- **Historic of International Climate Study:** the scientific knowledge is at the called fifth phase. Nowadays the theme concerns the planetary global dynamics. The world meteorological stations were founded about hundred and forty years ago. Those stations net are organized by the IMO (International Meteorological Organization). They are 29 core points over the planet surface. Headquarter is at Geneve- Swiss, and they are other three headquarters respectively at Washington, Moscow, and Melbourne.
- **Some Technical Attributes of Climate Study**: temperature, atmosphere pressure, air relative humidity, wind velocity and measure of rain follows.
- **Climate Theme National (Brazilian) Historic:** the first Meteorological Research Institution in Brazil was founded in 1909. This institution holds climate and astronomic researches together. The three core meteorological areas are meteorological, Hydrological and Agriculture Economics. For this, Brazil was divided in 8 districts. In 1969, the National department of Meteorological studies had already 10 districts. Since 1992, the National Institute of Meteorology was born. Now Brazil is already certificated by ISO 9001 for Meteorological Studies.
- **Climate Measure Instruments:** barometer, hygrometer, thermometer and pluviometric instrument.
- **A Brazilian Research Institute Example**: Sao Paulo Spatial Research Institute (INPE). INPE Institute uses to monitor forest fires, specially from Amazonas forest. It also deals with atmosphere phenomenon. The fires monitoring programming verify fires source according to three different identifiers: absence of rain falls, high temperature and less atmosphere pressure.
- **Climate District Research Work**: International model is intuition. Because it refers to weather forecast, researcher can create hypothesis to check together with the scientific method output. Those two parameters together will constitute the official weather bulletin.
- **Brazilian Meteorological Districts (each district name refers to different Brazilian regions):** 1) Amazonas, Acre, Roraima; 2) Para, Maranhao, Amapa; 3) Pernambuco, Ceara, Piaui, Rio Grande do Norte e Paraiba;4) Bahia, Alagoas, Sergipe;5) Minas Gerais;6) Rio de Janeiro, Espirito Santo;7) São Paulo, Parana;8) Rio Grande do Sul, Santa Catarina;9) Mato Grosso, Mato Grosso do Sul, Rondonia;10) Goias, Tocantins.
- **Brazilian Organizational District Division:** Each district is divided by meteorological stations. Brazil has about 450 meteorological stations. In the present case example, students belong to Santa Catarina brazilian region . The data about Santa Catarina meteorological district is of special interest for them.
- **Meteorological Stations of Santa Catarina District:** Santa Catarina district is the eighth national meteorological district. Santa Catarina meteorological district has about 30 meteorological stations.
- **Additional Technical Informations:** The agriculture climate bulletins output by Santa Catarina stations contains prognostics of five days to agricultural planning. This information can be updated but

its essence for the teaching methodology do not changes. Usually, prognostic of about hours has a 90% average positive result. It decreases to about 50% at the rate of 4 days.

- **Brazilian Climate Monitoring Services Devices:** Super computers with high performance are used to climate monitoring service. Parallel processors are used. Information to be updated always.
- **Prognostic Range Area:** in old times it has referred 100 X 100 km, after this, it has arrived to 40 X 40 km global and 15 X 15 km regional area. This data is to be carefully updated in accordance with new informations.
- **Brazilian Universities which Offer Courses in Climate Study:** Pelotas Federal University (Rio Grande do Sul state); Sao Paulo University (Sao Paulo state), Para Federal University (Para state) , Paraiba Federal University (Paraiba state), Alagoas Federal University (Alagoas state).

5.3. Example of Numerical Analysis Teaching Topic under Traditional Sequential Disciplines Curriculum Approach

Gregory Newton formula, G.-N., for interpolation, is a traditional method which belongs to the Numerical Analysis teaching. Traditional Engineering and also Computer Science curriculum usually contains Numerical Analysis discipline in the early years of university course. Usually, there is a sequence of teaching topics to arrive to the G.-N. formula. Later, different practical applications arrives. For example, how to calculate an interpolation value at climate study theme. Table 2, below illustrates the usual sequence of teaching tasks under a traditional Engineering and Computer Sciences curriculum. First, an introductory discipline to teaching Computer Programming shows how to calculate N factorial explaining about loops structures. Second, a Numerical Analysis discipline shows how to calculate an interpolation value in the Gregory-Newton formula using denominator N factorial calculus. Third, a Project or Information Systems discipline demonstrates how to calculate an interpolation value in a practical theme, like Climate Study theme. The interpolating value can be, for example, over Barometric measures offered by a regional district climate research unit.

Table 2. Numerical Analysis Topic Applied to Climate Study Theme

Topic	Discipline
1-N factorial	Introduction to Computer Programming
2-Gregory-Newton Interpolation method (embeds n factorial)	Numerical Analysis
3- Barometric Value Interpolation in Climate Study	Engineering Project/Information System

Table 2 illustrates traditional Engineering and Computer Science curricular approach. It shows isolated tasks (step 1 and 2) are presented to students waiting for future applications (step 3). Table 3 will present how it is presented the same idea under integrative curricular approach. In this case, it comes first, a wide theme and the sequence of knowledge, emerges somehow inverted way.

5.4. Example of Numerical Analysis Teaching Topic under Integrative Curriculum Approach

The difference from the sequential tasks (traditional curriculum approach) to arrive to a teaching topic of Numerical Analysis like the presented above, in 5.3, is that now, in integrative curriculum approach, the problem (project) already exists and it demands a specific and specialized knowledge which is presented to solve with aid of different disciplines.

Table 3. Numerical Analysis Issue under Integrative Curriculum Approach

Topic	Discipline
Gregory-Newton Interpolation method (embeds N factorial) in the Climate Study (barometric parameter interpolation, for ex.)	Introduction to Engineering Project / Computer System

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Table 2 can be compared with Table 3 example. In Table 2, the specific topics appear, isolated way. Practical application appears later. They refer to a mathematical, and, sometimes, to computer sciences programming topic. At the initial stages, they do not belong to a project itself. In Table 3, the project comes before the problem/ topic. It is possible this topic appears before the students have mathematical background to solve it. But the problem is saved carefully in a list of sequential projects proposal. The considered basic disciplines (Numerical Analysis or Computer Programming) now are considered specialized ones. What is called ‘ basic’ in the integrative logic paradigm is the theme discussion. After theme generic discussion it emerges a sequence of projects / problems to be solved during the whole course (Engineering or Computer Science Course).

6. Conclusion

The presented example implemented by the author for several years in different courses (Environmental and Sanitary Engineering, Computer Sciences and Information Systems), with different disciplines (Introduction to Computer Programming, Numerical Analysis I and II), under different computer tool support (Structured Pascal, Object Pascal), and different times life cycle (from 54 class hours until 108 class hours), shows it is possible to deal with integrative vision also under very traditional curricular organization, like the case of the presented pedagogic practice. Implementation of those ideas is open for new possibilities, under different curriculum approaches in accordance with each cultural context. The importance is to move on. The suggested introductory tasks about teaching method and wide theme approach are considered relevant to implement this pedagogic proposal with positive results even in traditional curricular organization.

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On the development of statistical models for assessing projects, portfolios and dissertations

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Abstract

Numerous assessment formats have evolved in higher education in recent years – many inspired by task-related activities in the workplace. Some are not new: at Masters level, the dissertation is long-established, whereas at undergraduate level, the use of projects and portfolios is becoming increasingly fashionable.

However, implementing these different forms of assessment is not always easy even when strict rubrics are enforced. As a consequence, double-marking is frequently used to offset the subjectivity of marks awarded. Unfortunately, this strategy too is not without its difficulties – as recent studies have shown – especially when there is fundamental disagreement between first and second examiners. Focussing on this issue of inter-marker conflict, a series of simple statistical models are developed to help assess how final marks might be more objectively determined.

Keywords: *Assessment, Dissertation, Double-Marking, Statistical Modelling.*

1. Introduction

At Master's level, the dissertation is a well-established and major form of assessment. Such is its success that recently it has been taking hold on undergraduate courses – as a dissertation *per se* or possibly in the form of a project report. In contrast, reflective portfolios – a widely adopted form of assessment on undergraduate programmes – have been finding increasing take-up at postgraduate and professional level.

In their study of a large sample of portfolios, Tomkinson and Freeman [1] found that though there was reasonable consistency between first and second markers, the mean marks awarded by those marking for the first time were significantly different from more established markers.

Subsequently, in 2011, the authors found worrying differences between dissertation marks awarded by different groups of markers on a Master's programme, As a result, changes were made to the ways in which markers were assigned in the programme and the authors have now had an opportunity to examine consequent results. A first impression is that ostensibly little had changed. However a more detailed analysis together with a short qualitative survey sheds valuable light on why this has happened and how corresponding arrangements might be made more equitable in the future.

2. The studies

Following on from previous work on a large cohort of Master's students [2] some changes were made to the procedures for marking students' dissertations. The principal change in procedure was to eliminate from the corpus of second markers a number of individuals who teach in unrelated subject areas. Instead, the supervisors of students were all invited to second mark. This was made possible by a smaller cohort for the year under investigation and also the funding of 'external' supervisors to carry out second marking. This meant that, in broad terms, the same body of individuals was responsible for second marking as was responsible for first marking. Where there was lack of close agreement between the two markers, the dissertation was referred to a third marker, drawn from a small subset of the markers. In the study, the effects of these third markers were subject to special investigation.

In addition, a small-scale survey was carried out of markers to solicit opinions on why differences in marking might have remained. The questionnaire used appears in the Appendix 1; this questionnaire was sent to 30 of the markers whose names and addresses were readily available and responses were received from 17, not all of whom responded to every question.

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3. Results

A comparison of the average percentage marks given by the first and second markers is shown in Table 1. These details give rise to a z value of 3.6, which is significant at the 1% level confirming the average percentage mark for the first marker is significantly higher than that for the second marker. Though this is clearly a matter of concern, the effects of the third marker also need to be examined.

Table 1. Summary Statistics by Marker

	First marker (supervisor)	Second marker
Mean % mark	63.88	60.30
SD	8.95	9.66

A third marker is used when the difference between the two marks is greater than 8 i.e. $|x_1-x_2| > 8$ and, in this cohort, 57 dissertations of the 178 sample (32.3%) were referred for third marking. Note that this figure compares with the percentage of 29.2% obtained for the 2011 study [1].

For the 121 cases where the difference was 8 or less, the final mark, y was estimated by averaging the first and second marks

i.e. $$\hat{y} = (x_1 + x_2)/2 \qquad (1)$$

When a third marker was involved in the marking, the rule was that the estimated final mark $\hat{y}$ had to fall within the range of the first two marks i.e. $x_1 \le \hat{y} \le x_2$. In practice it was found that $\hat{y}$ was consistently set below the average of the x_1 and x_2 limits.

A one-way analysis of variance of these third marks suggested that one marker had a significantly lower mean mark than the other third markers. It had always been assumed that third markers would bring a degree of consistency to the marking process but the presence of this one individual amongst third markers in this latest analysis appears to throw doubt on the theory.

A number of rival models were adopted for estimating the final mark when a third marker was involved. These were borrowed from the 2011 study.

In the first, significant differences between third marker mean marks were ignored yielding the regression formulation:

$$\hat{y} = \frac{x_1+x_2}{2} + \beta|x_1 - x_2| \qquad (2)$$

Using MINITAB, this model was fitted with an adjusted R square of 33.0% and $\beta\hat{}$ = -0.211. See Appendix 2 for details.

Whereas the term $\frac{x_1+x_2}{2}$ here reflects the agreement between the first and second marker, the term $|x_1 - x_2|$ is an indicator of the disagreement between the two markers. From our modelling results we deduce the estimated final mark is significantly reduced according to the level of disagreement between the first and second marker when a third marker is involved, β being a measure of the necessary adjustment.

To allow for the 'rogue' third marker, the following revised model was fitted to the dataset:

$$\hat{y} = \frac{x_1+x_2}{2} + \beta|x_1 - x_2| + \alpha D \qquad (3)$$

where D is a dummy variable which takes the value, 1 for the rogue marker in question (corresponding to cases 10-15 in the dataset) and 0 for all other third markers.

Using MINITAB, a significant model was obtained, for formulation (3) with R square = 47.3%, β = 0.158 and $\hat{\alpha}$ = -7.52. See Appendix 3. Subsequent Stepwise analysis revealed that that the latter model was a significant improvement on model (2). See Appendix 4.

By way of complete contrast, when a stepwise generalised linear model analysis of agreed dissertation marks by first, second and third markers was undertaken, the results in Appendix 5 were obtained. With an R square of 55% it not only has better goodness of fit characteristics than model (3) but, intriguingly provides a measure of first marker (supervisor) bias in the assessment – supervisors with initials JR, MK and AH evidently being preferred from a student perspective, to their JP and DW counterparts. (Note that interestingly, second and third marker factors were excluded from the model as not significant.)

Referring back to the significant difference between supervisors' and second markers marks in Table 1, what are the possible explanations? Whereas examination scripts are mostly anonymised these days this is just not possible for portfolios, dissertations and project reports. In the latter case, this is because markers are likely to know many of the students personally, even for large cohorts. John Archer and Barry McCarthy [3] suggest two principal forms of bias: stereotyping and 'halo' effects. They quote research that suggests that the student's gender and socio-economic background may influence the mark. Possibly, national or ethnic origins may also thought to be of relevance. The 'halo' effect relates more to the individual, where previous high marks can influence the marking. In examining the marking of undergraduate short research projects at the University of Edinburgh, Brian McKinstry and his colleagues [4] found that supervisors marked higher than second markers but attributed this to 'leniency in the supervisor resulting from the student being part of the supervisor's team'.

To investigate some of the preceding ideas a small survey was conducted, based on the questionnaire shown in Appendix 3. Although some results from this were revealing, the small numbers of respondents concerned means that many are not statistically significant.

Figure 1 shows the responses to question 2, which links with the statement "Some people are hard markers and others are generous markers". This figure shows that 69% of respondents agreed with the statement and 19% strongly so. None of the respondents disagreed with the statement. Although this is a significant result, the answer is perhaps self-evident and is confounded by the responses to questions 3 and 4 concerning individual self-perception, where most markers perceive themselves as being 'hard' markers.

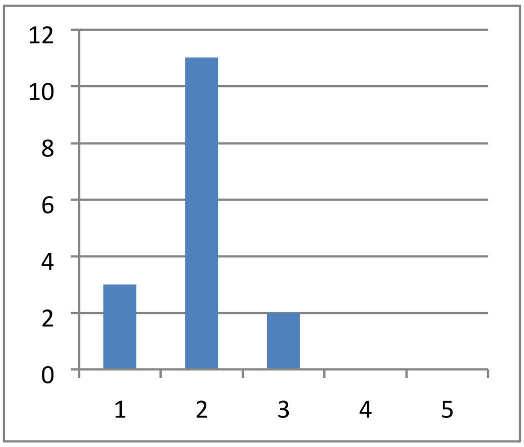

Figure 1. Hardness / generosity of marking

Since many of the responses were anonymous, it was not possible to check whether this perception was grounded in reality. However, in their additional comments three respondents indicated that their marking was designed to give a clear pass (or merit or distinction) or fail, where pass marks might be thought lenient in contrast to fail marks which might be considered harsh

Looking at possible supervisors' motivation, Figure 2 shows the responses to question 7, which limks with the statement "Supervisors tend to give higher marks than second markers because they understand better what the student is trying to say, particularly where the English is not good." This figure shows that 67% of respondents agreed with the statement and 7% strongly so. Only 7% disagreed with the statement and none strongly so. Again, the responses are statistically significant. It must be borne in mind that for the great majority of students on the programme English was not their first language.

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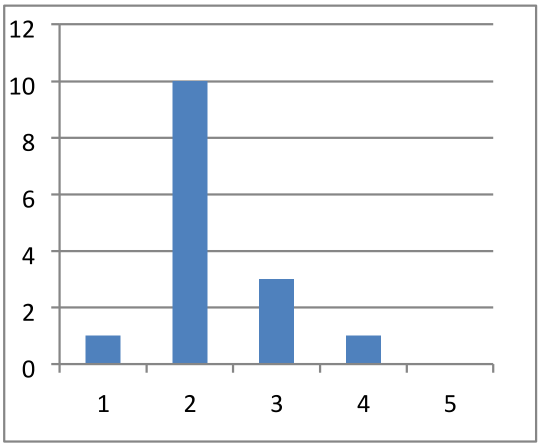

Figure 2. Supervisor bias

4. Conclusion

Previous work in 2007 had yielded the conclusions that first and second markers of portfolios did not differ significantly in their assessments except when one of them was marking for the first time. Also, significant differences in marking in the case of dissertations, was due, in part, to the large numbers of second markers who had no direct experience of the field of study. The present study shows that there are still differences between markers, with first markers tending to mark more highly, and that the practice of using third markers itself has problems. The principal reason for this is believed to be that supervisors (first markers) better understand what the students are trying to say. The cohort, studied, comprised largely students for whom English was not their first language and this may be one reason for feeling that supervisors understand them better. The argument used by some commentators that supervisors are more lenient markers attributes a greater degree of objectivity to second markers than evidence permits: there is a counter-argument that second markers are less familiar with the subject matter and the thought processes of the students and hence mark harshly. This counter argument suffers from the same lack of supporting evidence but is equally convincing. In truth, both marks are estimates of a ‘true’ mark for a dissertation or other piece of work and neither can be thought of as being more ‘accurate’ than the other.

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Appendix 1: Survey Questionnaire

Questionnaire

Dear Colleague

You will remember that I have been looking at differences between marks given by first and second markers, particularly on XX dissertations. The results so far have been a bit inconclusive, although a change has been made to the corpus of second markers as a result of the analysis. In order to try and find out a bit more about what is happening, I would like your help by responding to a short survey.

Please circle the appropriate answer in each line, where: 1 = Strongly agree; 2 = Agree; 3 = Unsure; 4 = Disagree; 5 = Strongly disagree:

1	I often disagree with the marks given by a second marker	1	2	3	4	5
2	Some people are hard markers and others are generous markers	1	2	3	4	5
3	I tend to be a generous marker	1	2	3	4	5
4	I tend to be a hard marker	1	2	3	4	5
5	I think that I probably give higher marks to my supervisees than to dissertations that I second mark	1	2	3	4	5
6	Markers tend to give higher marks to students that they know well	1	2	3	4	5
7	Supervisors tend to give higher marks than second markers because they understand better what the student is trying to say, particularly where the English is not good	1	2	3	4	5
8	Second markers tend to give higher marks than supervisors because they are less certain of what the marks should be and do not wish to disadvantage the students	1	2	3	4	5
9	Supervisors tend to give higher marks than second markers because they understand the subject of the dissertation better	1	2	3	4	5
10	Second markers are more objective than supervisors	1	2	3	4	5
11	I find it difficult to mark objectively because I do not know what the standards are	1	2	3	4	5
12	Differences in marks occur randomly and this is to be expected	1	2	3	4	5

Please add any further comments here:

Appendix 2: Model 2 results

Regression Analysis: Agreedmark-meanmark12 versus absdiff

```
The regression equation is
Agreedmark-meanmark12 = - 0.211 absdiff


Predictor        Coef   SE Coef       T      P
 Noconstant
absdiff     -0.21143   0.04021   -5.26   0.000


S = 4.96618


Analysis of Variance

Source           DF        SS        MS       F       P
Regression        1    681.87    681.87   27.65   0.000
```


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```
Residual Error  56  1381.13   24.66
Total           57  2063.00


Unusual Observations

Obs  absdiff  Agreedmark-meanmark12     Fit  SE Fit  Residual  St Resid
  7     17.0                  8.500  -3.594   0.684    12.094     2.46R
 10     24.0                -18.500  -5.074   0.965   -13.426    -2.76R
 20     35.5                 -0.750  -7.506   1.427     6.756     1.42 X
 26     16.0                  7.000  -3.383   0.643    10.383     2.11R
 33     31.5                 -6.750  -6.660   1.267    -0.090    -0.02 X
 47     29.0                -11.500  -6.132   1.166    -5.368    -1.11 X

R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large leverage.
```

Appendix 3: Model 3 results

Regression Analysis: Agreedmark-meanmark12 versus absdiff, D

```
The regression equation is
Agreedmark-meanmark12 = - 0.158 absdiff - 7.52 D


Predictor        Coef  SE Coef      T      P
Noconstant
absdiff      -0.15795  0.03854  -4.10  0.000
D              -7.519    1.943  -3.87  0.000


S = 4.44270


Analysis of Variance

Source          DF       SS      MS      F      P
Regression       2   977.43  488.72  24.76  0.000
Residual Error  55  1085.57   19.74
Total           57  2063.00


Source   DF  Seq SS
absdiff   1  681.87
D         1  295.56

Unusual Observations

Obs  absdiff  Agreedmark-meanmark12     Fit  SE Fit  Residual  St Resid
7       17.0                  8.500  -2.685   0.655    11.185     2.55R
9       27.0                -13.500 -11.783   1.846    -1.717    -0.42 X
10      24.0                -18.500 -11.310   1.828    -7.190    -1.78 X
11      12.0                 -6.500  -9.414   1.829     2.914     0.72 X
12      10.0                 -2.000  -9.098   1.840     7.098     1.76 X
13      26.5                -14.750 -11.704   1.842    -3.046    -0.75 X
14       9.0                 -7.000  -8.940   1.847     1.940     0.48 X
26      16.0                  7.000  -2.527   0.617     9.527     2.17R
34      20.0                -13.000  -3.159   0.771    -9.841    -2.25R

R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large leverage.
```

Appendix 4: Stepwise results

Stepwise Regression: Agreedmark-meanmark12 versus absdiff, D

```
  Alpha-to-Enter: 0.15  Alpha-to-Remove: 0.15


Response is Agreedmark-meanmark12 on 2 predictors, with N = 57


Step                 1       2
No constant

absdiff      -0.211  -0.158 T-Value
-5.26   -4.10
P-Value       0.000   0.000
D                      -7.5
T-Value               -3.87
P-Value               0.000
S              4.97    4.44
Mallows Cp     15.0     2.0
```

Appendix 5: General Linear Model: Stepwise results

General Linear Model: Final Dissertation Mark versus First marker, Second Marker, Third Marker

```
Method

Factor coding  (-1, 0, +1)


Stepwise Selection of Terms

α to enter = 0.15, α to remove = 0.15


Factor Information

Factor        Type   Levels  Values
First marker  Fixed      23  AG, AH, AW, BT, CK, CM, DW, IS, JN, JP, JR, KK,
                             ME, MK, MS, PC, PF, PG, PT, RY, SW, TLW, TR


Analysis of Variance

Source           DF   Adj SS  Adj MS  F-Value  P-Value
  First marker   22  3261.07  148.23     1.93    0.042
  Error          34  2614.97   76.91
  Lack-of-Fit    33  2574.47   78.01     1.93    0.524
  Pure Error      1    40.50   40.50
Total            56  5876.04


Model Summary

      S    R-sq  R-sq(adj)  R-sq(pred)
8.76988  55.50%     26.70%           *
```


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Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	61.16	1.37	44.57	0.000	
First marker					
AG	-2.16	6.08	-0.35	0.725	2.85
AH	10.18	5.03	2.02	0.051	2.30
AW	-2.16	5.03	-0.43	0.671	2.30
BT	-5.36	3.99	-1.34	0.188	1.86
CK	-3.16	8.49	-0.37	0.712	4.54
CM	8.84	8.49	1.04	0.305	4.54
DW	-14.16	6.08	-2.33	0.026	2.85
IS	-4.16	5.03	-0.83	0.414	2.30
JN	3.84	8.49	0.45	0.654	4.54
JP	-12.91	4.41	-2.93	0.006	2.02
JR	12.84	5.03	2.55	0.015	2.30
KK	-6.16	5.03	-1.22	0.229	2.30
ME	2.09	4.41	0.47	0.638	2.02
MK	8.59	4.41	1.95	0.060	2.02
MS	-0.16	5.03	-0.03	0.975	2.30
PC	9.84	8.49	1.16	0.255	4.54
PF	-1.16	8.49	-0.14	0.892	4.54
PG	-3.16	8.49	-0.37	0.712	4.54
PT	-9.16	8.49	-1.08	0.288	4.54
RY	10.84	8.49	1.28	0.210	4.54
SW	0.34	6.08	0.06	0.955	2.85
TLW	4.59	4.41	1.04	0.305	2.02

Regression Equation

Final Dissertation Mark (rounded)

```
 = 61.16 - 2.16 First marker_AG
+ 10.18 First marker_AH - 2.16 First marker_AW
- 5.36 First marker_BT  - 3.16 First marker_CK
+ 8.84 First marker_CM  - 14.16 First marker_DW  -
4.16 First marker_IS  + 3.84 First marker_JN
- 12.91 First marker_JP + 12.84 First marker_JR
- 6.16 First marker_KK  + 2.09 First marker_ME
+ 8.59 First marker_MK  - 0.16 First marker_MS
+ 9.84 First marker_PC  - 1.16 First marker_PF
- 3.16 First marker_PG  - 9.16 First marker_PT  + 10.84 First
  marker_RY + 0.34 First marker_SW
 + 4.59 First marker_TLW - 8.16 First marker_TR
```

Fits and Diagnostics for Unusual Observations

Obs	Final Dissertation Mark (rounded)	Fit	Resid	Std Resid	
34	44.00	59.00	-15.00	-2.09	R

R Large residual

Author

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Fundamental problem-solving skills are found across the board in education: Are our power engineering students on-board?

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Abstract

Fundamental problem-solving skills are common to many disciplines and could be found to exist across the board in all forms of education, including Power Engineering. Industrial Projects IV is a compulsory capstone module for students enrolled for the postgraduate Baccalaureus Technologiae (BTech) in Electrical Engineering (Power) in South Africa. This module makes use of project-based learning to prepare student graduates for further postgraduate studies in terms of Masters and Doctoral degrees. This module does not involve the physical construction of an electronic project, but considers case studies from Industry where million rand projects need to be implemented to solve existing problems which may include network, substation or feeder strengthening. The purpose of this paper is to assess a singular Industrial Projects IV dissertation with regard to project-based learning principles where fundamental problem-solving skills are involved. These skills include identifying and understanding a problem and developing and evaluating alternative solutions. An illustrative case study is used where qualitative data is analysed in terms of a singular Industrial Projects IV dissertation. Quantitative data is also presented, in the form of the final dissertation grades for all Industrial Project's IV students for 2014 which is an indication of whether they successfully achieved the fundamental problem-solving skills. These results suggest that not all engineering students mastered these skills, leading to the conclusion that not all engineering students are on-board when it comes to problem-solving.

Keywords: *Industrial Projects IV, capstone, skills, dissertation, assessment*

1. Introduction

"Economists who have studied the relationship between education and economic growth confirm what common sense suggests: The number of college degrees is not nearly as important as how well students develop cognitive skills, such as critical thinking and problem-solving ability". These words by Derek Bok, an American Lawyer and author of the book entitled "Our Underachieving Colleges", highlights a very important point. Helping some students in higher education to develop problem-solving skills (PSS) is more important than just awarding a large number of degrees. The degree in itself does not indicate that the student has acquired any PSS, but is simply an indicator that the student passed all of the required modules or subjects. Capstone modules form a crucial part of many higher education programmes where student acquisition of fundamental problem-solving skills can be assessed. These modules became increasingly popular in the higher educational sector of the United Sates as a means of encouraging students to draw their learning together at the end of their programmes [1]. Capstone modules often overlap with problem-based learning [2] and would therefore often require the assessment of PSS. Problem-based learning may be equated to project-based learning in the following way.

Project-based learning is defined as an important method which is used to make students acquire necessary knowledge, vital skills and citizenship values for the 21st century and includes portfolios, performance assessments and written reports [3]. Donnelly and Fitzmaurice [3] define project-based learning as an "individual or group activity that goes on over a period of time, resulting in a product, presentation, or performance". However, problem-based learning may occur within one module, or even within one practical experiment covered in a module [4]. So while there are subtle differences between project-based and problem-based learning, it may be fair to say that the one includes aspects of the other, as solving a problem does not necessarily include executing a project in the formal sense [5]. Project-based learning is used in Industrial Projects IV (IP4), which is a capstone module offered over a period of one calendar year, where students need to compile a portfolio of written reports evaluating different solutions to a specific real world problem. This project-based learning approach, which includes problem-based learning, requires students to submit a final report or dissertation which is based on the structure of a Master's degree and has the sole purpose of assisting students to prepare for further postgraduate studies.

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However, it is recognised that some students struggle with problem-based learning. This has been documented in the field of automation [6], geography [7] and nursing [8]. The research question therefore arises: "Do undergraduate Power Engineering students struggle with problem-based learning which is fundamental to many programmes in higher education, or are they all on-board when it comes to demonstrating specific PSS"? The purpose of this paper is to assess a singular IP4 dissertation with regard to project-based learning principles where specific PSS are involved. Fundamental PSS are firstly established and then the course structure of IP4 is outlined. An illustrative case study using an explanatory mixed method design is then introduced and substantiated in the methodology section. The assessment of a singular IP4 dissertation is then given along with the final grades of students registered during 2014.

2. Fundamental problem-solving skills

The purpose of a capstone module is to provide the opportunity for participants to earn credits by integrating and applying the knowledge and skills acquired from each of the other modules so as to extract the best possible benefit from the programme in a particular career [9]. The integration of knowledge and skills in an electrical engineering capstone module often involves the design and development of an engineering project [10]. Large research projects within capstone modules have also been used for postgraduate Master's degrees [11] while many of these modules lend themselves readily to problem-based learning [12] where fundamental PSS need to be assessed. PSS include being able to identify and understand a problem and then to develop potential solutions [13, 14]. Rational PSS further include evaluating and choosing the best solution [15]. These citations are based on research in construction management, PhD attributes, clinical psychology, elementary school principals, institutional decision-making, mathematics, software engineering, and oil recovery. However, these PSS are also encapsulated in the graduate attributes defined by the International Engineering Alliance [16] to which the Engineering Council of South Africa is a signatory. This highlights that fundamental PSS are generic to all disciplines, including Power Engineering. These skills with their requirements are indicated in Table 1 and are applied within the Power Engineering context for IP4. These skills form the acronym iUSE, where each letter is used to represent a specific PSS.

Table 1. Key generic PSS and their requirements

PSS (iUSE)	Requirements
Identifying the problem (Chapter 1 of the dissertation)	Identifying a problem requires simplicity in the presentation of data or information (quantitative or qualitative) and can be made more effective by the use of graphics [17].
Understanding the problem (Chapter 2 of the dissertation)	The first step in understanding a problem is to build a mental picture of it, so that we can see it in our mind's eye and predict its behaviour [18].
Developing **solution**s (Chapter 3 of the dissertation)	Developing solutions requires the identification of alternatives, and assessment of relative costs and benefits of each alternative [19].
Evaluating the solutions (Chapter 4 of the dissertation)	Evaluating a solution often requires a simulation run [20], and especially so in Power Engineering where possible solutions can imply costs well beyond the million rand mark.

Identifying the problem requires that the problem statement be brief and to the point, which should be able to be accomplished in no more than five sentences. Graphics should be required to clarify and substantiate the problem, being given either directly before or directly after the problem statement. In Power Engineering, these graphics should include a geographical layout of the site where the problem is being experienced, a line diagram and proof of the problem (e.g. forecasted load growth, SAIDI performance indicators or feeder voltage profiles).

Understanding the problem requires building a mental picture of it, or compiling a well-structured written scientific report. This report or dissertation must include in-text references referring to similar studies which were done in the past, documenting the exact problem, implemented solution and subsequent results.

Developing the **solution** requires the student to use critical-thinking where the advantages and disadvantages of each alternative solution needs to be tabled. These solutions need to be relevant to the problem and be supported in the literature review. In other words, solutions similar to the proposed alternative solutions must have been used in previous studies or projects with good results.

Evaluating the alternative solutions must involve sketches or tables that need to be used to correlate the same parameter or principle in order to draw the correct conclusions. In Power Engineering, this often necessitates the use of common commercial software tools such as DigSILENT / PowerFactory, PSS/E, PSCAD, NE- PLAN, PSSE SINCAL and MATLAB / SIMULINK [21]. A financial analysis of the alternative solutions should also be contrasted in table form. Capstone modules need to integrate and harmonise the knowledge and skills from a variety of modules with the student's experience. However, the assessment procedures for capstone modules pose challenges and requires careful course structuring [22].

3. Structure of Industrial Projects IV

IP4 is a compulsory offering within the Baccalaureus Technologiae: Engineering: Electrical qualification, more commonly referred to as the BTech in Power Engineering. The course structure used at the Central University of Technology (CUT) for this module is shown in Table 2, which needs to be completed over a 1 year period (registration takes place in January with the final assessment in October). No formal electrical or electronic based project or operational circuit is required from these students. Their final summative report or dissertation is usually based on a real life case study which exists in Industry. The structure and purpose of the project proposal along with the research methodology course and project plan is covered with the students over the first 9 week period of the course. This usually comprises a singular 4 hour session per week arranged for a late afternoon in order to grant full time working students the opportunity to attend. Theory relating to the title, problem statement and proof of the problem is emphasized! The project proposal is assessed formatively, giving students the opportunity to rectify any deficiencies. This is important as the project proposal usually forms the core of the first chapter in the dissertation.

The progress report covers the first three chapters of the dissertation, along with the front matter (declaration, expression of thanks, abstract and table of contents), references (a minimum of 16 references are required of which at least eight must be journal references). The first chapter basically comprises the updated project proposal, while Chapter 2 should cover relevant literature that supports the problem and the alternative solutions. Students are requested to include specific references to previous Industrial projects where a similar problem to theirs was encountered. Implications of that problem along with its solution and results must be provided along with scientific references. Chapter 3 of the progress report should introduce at least three alternative solutions to the problem, presenting proposed electrical diagrams, possible installation sites, geographical topologies and the advantages and disadvantages of each solution.

The final summative dissertation comprises the largest weighting towards the student's final mark which is based on academic feedback given to the student with regard to the progress report (Chapter 1 – 3). The final dissertation must include chapter 4 (results section comparing the alternative solutions by means of simulation software) and chapter 5 (conclusion of the project substantiating the use of the preferred solution along with pertinent recommendations). However, 40% of the final dissertation is awarded to the structure of the portfolio, the front matter (declaration, expression of thanks, abstract and table of contents) and the back matter (references and annexures). Therefore it is appropriate to consider only 60% of the final dissertation as an indication of whether students have successfully achieved the PSS skills listed in Table 1, which is indicated in the following research methodology section.

Table 2. Course structure of IP4

Requirement	Month of submission	Final grade weighting
Project proposal and plan	April	10%
Research methodology test	June	0%
Progress report	July	10%
Article	August	5%
Poster	August	5%
Oral presentation	September	10%
Final summative report	October	60%

4. Research Methodology

An illustrative case study using an explanatory mixed method design is used. Illustrative case studies are descriptive where one or two instances or "slices of life" are used to illustrate a situation [23]. In this research, the situation is the demonstration of specific PSS by a singular Power Engineering student during 2014. A case study also intends to explore a bounded system in-depth [24]. A system could refer to a programme, event or activity (in this research it is a final dissertation for IP4), while the word bounded implies that the research is

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conducted within the boundaries of a specific place (in this research it is the CUT). A singular case study was used by Lajoie et al. [25] to describe in detail an online international problem-based learning approach.

In explanatory mixed method designs, the qualitative component is primary and is used to generate theory or specific theoretical constructs [26]. The quantitative component is used in the service of the qualitative component. Qualitative data is primarily used as the final dissertation of a singular Power Engineering student is analysed in terms of the PSS outlined in Table 1. Approval to use this dissertation in a conference paper was given by the student, who is also the co-author for this paper. Quantitative data is then used to determine how many Power Engineering students obtained 50% or more for the section within the dissertation dealing specifically with PSS. This quantitative data is given in the form of the final throughput rate of the module and the individual student grades obtained for the final dissertation. The throughput rate is not an absolute indicator that students achieved the specific PSS listed in Table 1, and is defined as the number of students enrolling for the module as compared to the number of students successfully completing the module. The final student grades need to be multiplied by 0.6 (final dissertation counts 60% towards the final grade – see Table 2) and then again multiplied by 0.6 (only 60% of the final dissertation considers PSS where the other 40% is awarded to the structure of the portfolio, front matter and back matter as previously discussed). This quantitative data is then analysed using a histogram, where students achieving more than 50% were viewed as achieving the desired PSS. The final grade results (quantitative data) would therefore inform the research question if all Power Engineering students are on-board when it comes to demonstrating specific PSS (qualitative data from a dissertation). The assessment of all the Power Engineering students' dissertations for 2014 followed the same process as that outlined below for the singular dissertation.

5. Assessment of a singular Industrial Projects IV dissertation

5.1. Student identification of the problem

Student project title

Establishment of a new Kathu-West 132/11 kV substation in the Northern-Cape province [27].

Student problem statement

The existing Kathu substation has three 20 MVA 66/11 kV transformers that can provide a total capacity of 60 MVA power load. In case one of the transformers fails, the maximum firm supply capability from the substation will be 40 MVA. The Kathu substation is currently sitting on 26.5 MVA load with a new request of an additional 40 MVA firm supply from the Gamaraga municipality. If this additional load is to be fed from the existing Kathu substation with the current setup, the substation will overload and run the risk of failure [27].

Student proof of the problem

Figure 1 presents the load flow analysis of Kathu substation, where the installed capacity and forecasted load growth is visible. It illustrates that, with the forecasted load growth, by 2022 3.2 MVA of customers will be unsupplied and the substation will need to be reinforced. It further highlights that if the new industrial customers from Gamaraga municipality (40 MVA) are supplied from the existing network, Kathu substation will not cope which will result in a detrimental effect to the customers [27].

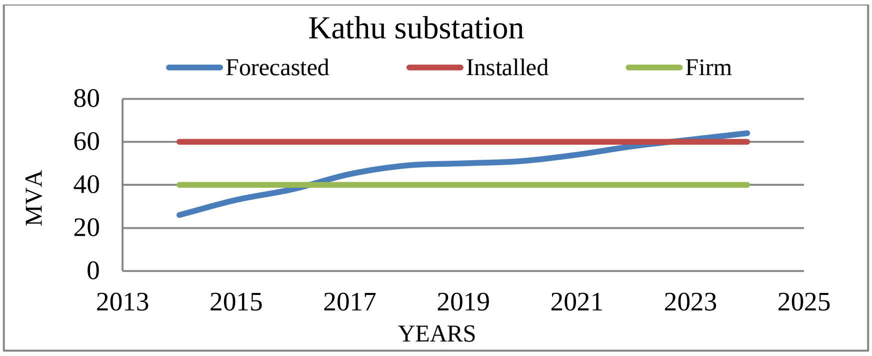

Figure 1. Forecasted load growth versus installed capacity and firm supply as proof of the problem [27].

Academic assessment of the identification of the problem

Academics need to ensure that the title clearly indicates the overall scope of the project. In this case, the student proposes a new substation for a specific region in the country. Possible reasons for this could be due to new industrial, commercial or residential developments or due to the fact that an existing confined substation can no longer provide the required demand. Academics now need to determine the validity of that title by reviewing the problem statement which needs to be supported by physical proof. Academics can discern from this problem

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statement that the existing Kathu substation is inadequate to provide additional power to the Gamaraga municipality, necessitating the establishment of a new substation called Kathu-West. This should already highlight to the examiner the student's preferred solution to the current problem and create anticipation for the next section which should prove that the current substation is constrained and limited in physical size. The inclusion of Figure 1 by the student illustrates the forecasted growth and proves that the additional 40 MVA cannot be catered for at the moment.

5.2. Student understanding of the problem

Chapter 2 will cover the literature review of load forecast, site selection, material selection for a new substation and expected life cycle costs. Individual sources and their applicability to this study are therefore presented [27].

Academic assessment of the understanding of the problem

This is the student's introduction to Chapter 2, which covers the literature review. The student obviously wants to discuss the merits of load forecasting, which has been used to support the problem. This is good, as the literature review should always seek to support the problem and the alternative solutions. This is hinted at by the words "site selection" and "material selection for a new substation". However, what this student did not cover was previous examples of where a similar problem occurred, along with its specific solution and results. This would add force to the alternative solutions and especially to the preferred solution if the results from a previous similar study were presented by means of scientific references.

5.3. Student alternative solutions to the problem

Alternative solution 1 – Increase the capacity of the existing substation. This alternative involves increasing the capacity of the existing Kathu substation. The current setup of Kathu substation is 3 x 20 MVA transformers connected between a 66 kV HV busbar and a 11 kV LV busbar. The firm supply capability of this substation is 40 MVA which can be upgraded to 60 MVA by the addition of a new 20 MVA transformer. Table 3 outlines the advantages and disadvantages of this alternative, clearly indicating that it is not possible to increase the switchyard footprint, rendering this alternative obsolete [27].

Table 3. Ads and disads of increasing the capacity of the existing substation [27].

Advantages	Disadvantages
No need to upgrade the existing 66 kV line	The problem with this option is that the existing substation is in a densely populated area, so increasing the switchyard footprint to accommodate the new transformer and switchgear is impossible
Provides additional 20 MVA in the service area	It will be adequate for only four to five years due to the on-going developments in and around the area that this substation is serving

Alternative solution 2 – Establish a new 2 x 40 MVA 132/11 kV substation at Kathu-West. This substation will be next to the new industrial area and will be feeding from the newly constructed Ferrum – Umtu 132 kV transmission line. Table 4 discusses five distinct advantages as compared to two disadvantages of this alternative solution. A key advantage here is the provision of the n-1 contingency which indicates that when one transformer requires planned maintenance, the second transformer will still be able to provide continuous supply to the new proposed connection required by the Gamagara municipality. It must be emphasized that the existing Kathu substation will be retained [27].

Table 4. Ads and disads of establishing a new 2 x 40 MVA 132/11 kV substation at Kathu-West [27].

Advantages	Disadvantages
If any of the transformers is down there will always be continuity of service	Land acquisition
Maintenance of the busbar, circuit breakers and transformers can be performed without affecting continuity of service	Two transformers needed
Sectionalized busbar will ensure that with any busbar fault or circuit breaker failure the entire station is not shut down	
Reliability improvements and operational savings	
Higher system voltage reduces electrical losses	

Alternative solution 3 – Establish a new 1 x 80 MVA 132/11 kV substation at Kathu-West. This substation will be next to the new industrial area and will be feeding from the newly constructed Ferrum – Umtu 132 kV transmission line. Table 5 discusses the advantages and disadvantages of this alternative indicating many disadvantages as compared to advantages. The most notable disadvantage is the lack of providing the n-1 contingency [27].

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Table 5. Ads and disads of establishing a new 1 x 80 MVA 132/11 kV substation at Kathu-West [27].

Advantages	Disadvantages
Higher system voltage reduces electrical losses	The problem with this option is that failure of the circuit breaker or any busbar fault will cause loss of the entire substation
	Only one transformer, so transformer failure will affect the entire station
	Transformer maintenance will require total loss of service
	Transformers above 60 MVA are difficult to transport by road
	Land acquisition

Academic assessment of the solutions to the problem

Academics need to clearly see that the student can contrast the alternative solutions with regard to specific parameters or principles. These are clearly visible by means of the tabled advantages and disadvantages, where alternative 2 stands out in terms of firm supply and redundancy.

5.4. Student evaluation of the solutions

Figure 2 illustrates the new Kathu-West substation where 2 x 40 MVA 132/11 kV transformers or 1 x 80 MVA 132/11 kV transformer is installed. A provision for an additional load is made should the load demand increase beyond our forecasting. This figure illustrates the same load flow analysis for both alternative 2 and 3, although only alternative 2 will have a firm supply if scheduled or unscheduled maintenance is taking place [27]. Table 6 covers the cost components of all three alternative solutions. Alternative 1 is having the highest acquisition cost while alternative 2 has the lowest. Alternative 3 is having the highest scheduled and unscheduled operating and maintenance cost due to the fact that it has only one transformer and one busbar [27].

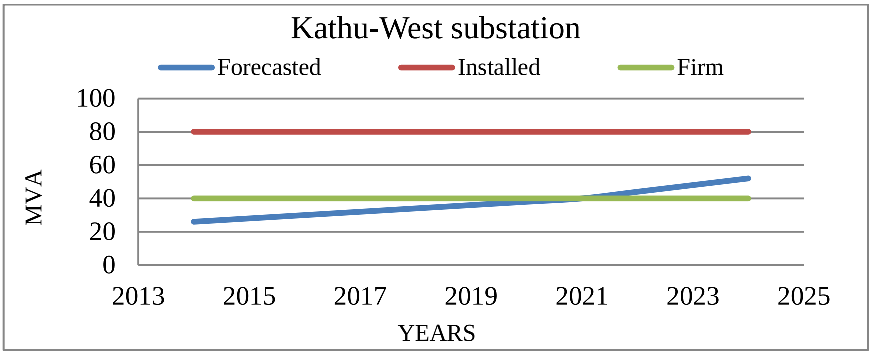

Figure 2. Forecasted load growth versus installed capacity with only alternative 2 having a firm supply [27].

Table 6. Project net summary results (net present cost base year 2014) [27].

Item	Alternative 1	Alternative 2	Alternative 3
NPC Acquisition	R49 529 506	R33 466 913	R41 358 997
NPC Losses	R18 312	R18 312	R515 467
NPC O&M Schedule	R50 376	R50 376	R150 327
NP O&M Unscheduled	R6 748 705	R8 455 989	R17 564 967
Life-Cycle Cost to company	R56 023 610	R41 603 643	R59 589 759
NP Customer Interruption Cost	R56 023 610	R56 605 831	R59 589 759
Life-Cycle Cost to company & customers	R112 629 441	R56 605 831	R146 296 258

Alternatives 1 and 2 have similar results on NPC losses, scheduled maintenance and NP interruption cost which is influenced by the system redundancy. A power transformer may take up to 30 days to replace, hence influencing the net present customer interruption cost as shown for alternative 3. Alternative 2 indicates the lowest life cycle cost, while also including the additional engineering advantage of the n-1 contingency. This redundancy may incur a higher initial cost investment, but will reduce the probability of total system failure and subsequent lower penalty costs in the long run [27].

Academic assessment of the evaluation of the solutions

The student has been able to improve on Figure 1, which was the original proof of the problem. The student has also been able to contrast alternative 2 and 3 in terms of installed capacity and firm supply by making use of a singular sketch. Academics also need to discern that students are able to contrast the financial aspects of all three alternatives. In this regard, the student makes a final recommendation of establishing a new Kathu-West substation with 2 x 40 MVA 132/11 kV capacity to ensure firm supply at the lowest life-cycle cost to company.

6. Final student grades

Figure 3 presents a histogram of the grades relating to PSS (0.6 of the final grade to calculate the dissertation grade and then again 0.6 of that value to calculate the PSS grade). This distribution highlights that 17 students were not able to demonstrate the required skills, with 12 of these students lying in the 40-49% bracket. The final throughput rate for the module was 70% (considering all weightings given in Table 2) and the final percentage of students who achieved 50% or more for the PSS section within the final summative dissertation was also 70%. Descriptive statistics of the results highlight that the mode was 50 (most occurring grade) while the median was 52 (half of the enrolled students lie above this grade). A low kurtosis value of less than 3 indicates a relatively flat distribution, which is evident in Figure 3 for student grades between 40 and 60%.

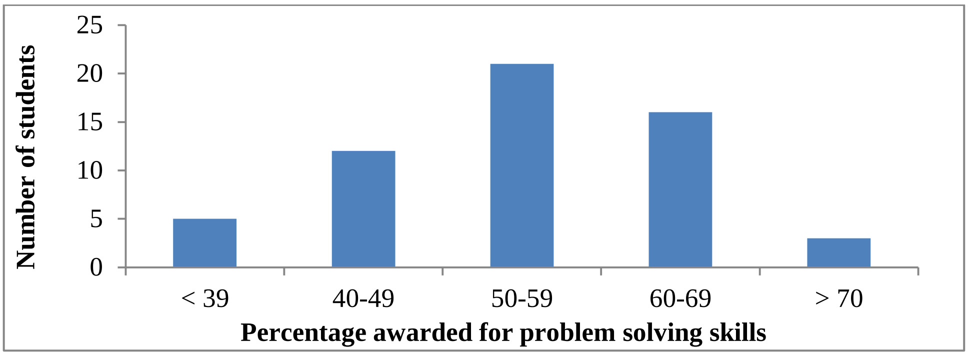

Figure 3. Number of students who achieved specific percentages for the assessment of their PSS

7. Conclusions

The purpose of this paper was to assess a singular IP4 dissertation with regard to project-based learning principles where specific PSS are involved, illustrating its usefulness in capstone modules. These skills included identifying and understanding a problem and developing and evaluating alternative solutions. The assessment of the singular IP4 dissertation revealed that the student could identify a problem and provide logical proof to support the problem. Student understanding was demonstrated by the literature review while three alternative solutions were suggested and then successfully evaluated with regard to advantages, disadvantages, forecasted load growth, redundancy (n-1 contingency) and financial implications. Overall results of the students with regard to only that part of the final dissertation that considers PSS revealed that 70% of the students could indeed achieve the four specific skills (iUSE) outlined in Table 1. This indicates that not all engineering students are on-board when it comes to demonstrating fundamental PSS. Flagging these students during the course after completing the assessment of their first progress report is vital if they are to develop the required cognitive skills. Additional academic support should then be given to these students in order to enable them also to develop the fundamental PSS that are generic across the board for education.

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The Role of Marketing Strategy Simulation in Assurance of Learning

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Abstract

In this paper the comprehensive case study will be presented which illustrates how business simulation can be used to augment learning and how it can contribute to many of assurance of learning requirements. There are three approaches to achieving knowledge integration in marketing strategy simulation courses: theoretical, applied, and practical. Simulation enables students to build the practical integration skills in a risk-free environment so that they can make better decisions in their real business environment. The paper will also discuss how distance learning pedagogies can actually improve classroom teaching. It is clear that no single assessment tool can fully meet the assessment requirements of either a course or a curriculum. Paper will illustrate an assortment of enhancements and assessment tools that can expand learning opportunities and provide a variety of feedback information about students' knowledge, skills, and reactions to various market challenges. It will display the process of measurement methods and rubrics selection used to measure student outcomes, as well as the process of setting the acceptable results. This paper will present the approaches to "closing the loop" for several learning goals: knowledge in new and unknown circumstances through conceptual understanding of marketing strategy; capacity of critical and analytical thinking; usage of new technologies; oral and written communication skills, and student work in teams.

Keywords: *assurance of learning, "closing the loop", distance learning, marketing strategy, simulation*

1. Introduction

The paper tries to support earlier research which suggests that active learning techniques such as simulation games can enhance student learning outcomes [1] [2] [3]. Authors argue that in addition to lectures and learning, students need to be immersed in some kind of a real business environment adapted for educational purposes. Simulation games such as Marketing Strategy Simulation (MarkStrat) mimic a real business ecosystem so that students can gain experience, test their decision-making, and check their fit for the competitive business settings. Just as pilots use simulations to prepare for a real flight, marketing students use simulations to better understand how their actions can affect company performance before they actually take an action in a setting that will not tolerate rookie mistakes. This risk-free environment enables students to practice specific skills such as problem solving, cooperation and teamwork, and decision-making [4] [5] [6]. Authors believe that traditional didactic methods still remain essential, but argue how they need to be supported by a simulation of reality.
Another aspect of this paper is the evaluation of effectiveness of integration of distance learning within the active learning techniques. Markstrat simulation enables students to make periodic decisions both in the classroom, and at home. In that way it once again mimics the fast-paced business environment, where students are compelled to use video conferences, virtual meetings, and other web-based technologies as they most probably will in their future business settings. Lecturers can therefore evaluate how students utilize different online technologies for better teamwork and successful decision-making. According to a meta-analysis done by the U.S. Department of Education, students who took all or part of their course online performed better, on average, than those taking the same course through traditional face-to-face instruction [7]. This paper uses the comprehensive case study which illustrates how marketing simulation can be used to augment learning and how it can be used for measuring student learning goals set within the assurance of learning project (AOL) at the Zagreb School of Economics and Management (ZSEM).

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2. Mission-driven assessment strategy at ZSEM

The development of the Zagreb School of Economics and Management assurance of learning process starts with the mission statement of ZSEM. The mission of ZSEM is to transfer **values**, **knowledge**, and **skills** that students need for long-term success in a **globalized business** world undergoing constant **technological** and market transformations. This statement defines the direction for the ZSEM as an institution and is leading it to the specification of the learning goals supported by their objectives for each program. The ZSEM has set six goals and objectives for the graduate MBA Program in Marketing which comes from the mission statement and refers to the knowledge and skills that students need to acquire. The learning goals and objectives for MBA Program in Marketing are [8]:

Learning goal 1: ZSEM students will have internalized a value system where ethics and corporate social responsibility are important.

> *Objective:* The students will be able to identify the problems of ethics and corporate social responsibility, as well as forecast costs and benefits of ethical conduct related to a company's business.

Learning goal 2: ZSEM students will be able to apply the acquired knowledge in new and unknown circumstances through conceptual understanding of certain fields within the discipline of Marketing.

> *Objective:* The students will study different literature from the field of Marketing. They will link theoretical knowledge with real business cases. When they face a business problem, in order to solve it, they will apply adequate methods, coming from different fields of Marketing.

Learning goal 3*:* ZSEM students will have the capacity of critical and analytical thinking.

> *Objective:* The students will discover problems and offer possible solutions, as well as identify possible risks of a proposed solution.

Learning goal 4: ZSEM students will have the capacity for adaptation which is necessary for doing business in the global environment.

> *Objective:* The students will identify key global trends in their discipline and discuss the influence of those trends on the entire activity of a company.

Learning goal 5: ZSEM students will communicate effectively in a way appropriate for management positions.

> *Objective:* The students will develop interpersonal and communication skills needed by business, such as teamwork, oral and written communication, and presentation skills.

Learning goal 6: ZSEM students will be able to use new technologies.

> *Objective:* The students will know how to use information technology in the delivery of course projects and results of their analysis.

As can be seen from goals and objectives, within the different courses of the MBA Program in Marketing, high ethical values are fostered. Aside from acquiring knowledge of key areas of marketing, students need to develop problem-solving skills and critical and analytical thinking, which are necessary for a successful career in the discipline. Taking into consideration the global nature of business and the constant technological and market changes they are exposed, students are taught how to do business in a global environment, while respecting the economic and other issues specific to our geographical area. Besides that, students are expected to be good communicators, to be able to express themselves in writing as well as orally, so a lot of emphasis is placed on perfecting communication skills and team work of each student. Team-working skills are developed in order to enable students to work well with others and carry out their responsibilities in team projects. Finally, one of the goals is to encourage the use of modern technologies and improve computer skills.

3. Assessment process at ZSEM

Goals and objectives graduate of MBA Program in Marketing are a starting point for determining the goals and objectives of each course in the program. Thus, in the course Marketing Simulation - MarkStrat four goals that describe what students will achieve on the course are determined, and from them objectives that describe what students should specifically do to achieve it are derived. Objectives are described in the syllabus with active verbs that are underlined in Table 1. Objectives are indicated outcomes that have been developed to assess each individual student directly.

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Table 1: Goals and objectives from syllabus of MBA course Marketing Simulation – MarkStrat

	General goals of the course:	Objectives of the course:
1.	Students will be able to apply the acquired knowledge in new and unknown circumstances through conceptual understanding of marketing strategy. Students will recognize the importance of market research as a basis in developing marketing strategy.	Students will **recognize** the importance of situation analysis in marketing planning, realizing the integrative nature in development of marketing strategy.
2.	Students will have the capacity of critical and analytical thinking. Students will develop an ability to make marketing decisions, as a part of corporate decisions. Students will understand the importance of marketing expenses and pricing.	Students will **develop** the integrated marketing program and **explain** how the marketing decisions are connected with the other functions of the firm (R&D, Production, Finance, etc.). Students will **apply** the market and financial concepts in experimental way.
3.	Students will be able to use new technologies.	The students will **practice** how to use the Markstrat simulation and their results.
4.	Students will communicate effectively in a way appropriate for management positions. Students will develop skills in team work and improve their ability of oral and written communications.	Students will **work** in teams. They will **analyze** results of some 15 market research projects, **make** marketing **decisions** based on available data, **analyze** result of their decisions and **make** necessary **changes** in their marketing plans (or strategies). (The team work will be monitored and mentored by the professors.) Participating, helping, and sharing will be encouraged. At the end they will **analyze** their complete work and **prepare** business reports and final presentations.

After all syllabi were aligned, the goals that need to be achieved in every course are mapped. Table 2 shows the mapping process for the MBA Program in Marketing.

Table 2: Mapping goals of the graduate MBA Program in Marketing

Name of the course	1. goal – Ethics & CSR	2. goal – business knowledge	3. goal – critical and analytical thinking	4. goal - global environment	5. goal- communication skills	6. goal- new technologies
MBA Marketing						
Marketing Research			+		+	
Services Marketing		+	+	+		
Marketing Metrics		+	+			
Distribution and Logistic Management		+	+	+		
Consumer Behaviour		+		+		
Product Design and Management		+	+			
International Marketing				+		
Integrated Marketing Communications		+			+	
Price Management		+		+	+	
Marketing Strategy Simulation		+	+		+	+
Business Ethics	+	+		+	+	

After this mapping it can be seen which goals are present in which courses (Figure 1). It is very important to take into consideration if all goals are included in the program and determine courses in which each goal can be measured (Table 2). This analysis is the basis for drafting the measurements plan that contains information about which goal is measured on which course using which specific method and measuring instrument.

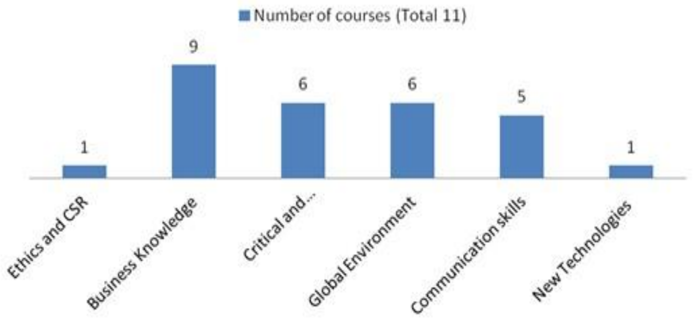

Figure 1. Number of courses fulfilling certain goal in MBA Program in Marketing

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The MBA Marketing program started in the academic year 2006/2007 and the first measurements started in academic year 2008/2009 as can be seen in Table 3.

Table 3. Assessment Plan for Graduate MBA Marketing program

1st cycle of measurement	2nd cycle of measurement	3rd cycle of measurement	4th cycle of measurement	5th cycle of measurement	6th cycle of measurement
2008/09	2009/10	2010/11	2011/12	2012/13	2013/14
All goals and objectives were measured	All goals and objectives were measured one more time	Only goals and objectives which are not fully achieved in the 1st and 2nd measurements were measured	1. goal: Ethics & CSR, and 2. goal: Knowledge + goals and objectives which are not fully achieved in the previous cycle	3. goal: Critical and analytical thinking, and 4. goal: Global environment + goals and objectives which are not fully achieved in the previous cycle	5. goal: Communication skills, and 6. goal: New technologies + goals and objectives which are not fully achieved in the previous cycle

The faculty in charge of the courses were responsible to include a measurement of a chosen goals and objectives into the course, and to conduct the measurement accordingly. Before the measurement they select or create the most appropriate measurement instrument - rubric. Brainstorming sessions were scheduled in order to create those instruments. After completing the measurement it was possible to analyze results and make reports. At the end, the changes were implemented if necessary. The whole Assessment process at ZSEM is shown on Figure 2.

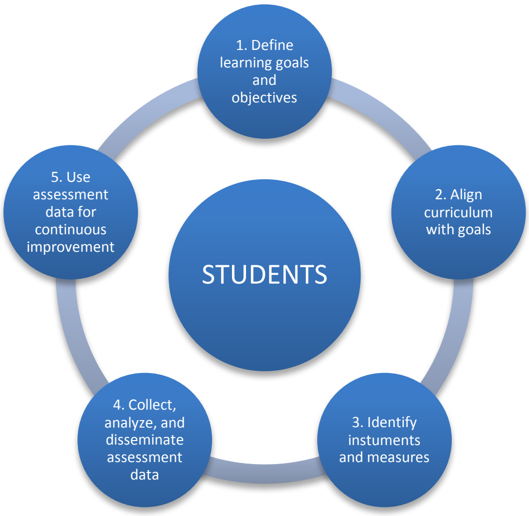

Figure 2. Assessment process at ZSEM

In the first two cycles, the direct measurements at the MBA Program in Marketing included a large number of courses in order to assess the situation regarding all goals within the program. In addition to measuring, faculty members also participate in other activities, such as: development of measuring instruments, implementation of changes within the curriculum etc. In this sense, 100% of faculty members are involved in the AOL process.
Results of measurements are discussed at the brainstorming sessions with all faculty members. Depending on a type of changes, implementation of changes and improvements are the responsibility of various faculty members who are in charge for courses, or the Quality Committee if the necessary changes were implemented in the program. There have been courses, program and organizational changes. These changes include, but are not limited to: allocating more time to certain skills; changing the syllabus; introducing new material/content to some courses; devoting extra time to explaining certain material/content; re-allocating in-class time; changing the grading system, adding new elements to the assessment of certain skills; improving the use of rubrics (the students were given the rubrics in advance and were familiarized with all the evaluation elements); adapting the rating scale; etc. With the implementation of changes we close the loop on the assessment process.

4. Marketing Simulation – MarkStrat course in assessment process

4.1. An introduction to course

Marketing Simulation – MarkStrat course is designed to provide an in-depth understanding the job of a typical manager in marketing departments. While the specific duties of a marketing manager vary considerably across industries and companies, the course focuses on the four major activities common to the position: (1) analysis of market information, (2) developing a marketing strategy, (3) programming the strategy, and (4) implementation. The course draws knowledge and skills from a variety of areas, including marketing strategy, consumer behavior, market research and statistics, and attempts to simulate the marketing manager's job through the development and implementation of a marketing plan in the context of MarkStrat simulation [9]. Besides working on simulation, the course hours are used for discussions on marketing strategy, market research techniques, segmentation and product positioning, product and price management, sales forces, and advertising management. Students work in teams both in the classroom, and from home, and have an open possibility of continuous discussion with professor in class and through e-learning platform- Blackboard. Their results are also openly discussed. The teams are comprised of the three to four students each, observed and mentored by the professor.

4.2. Grading and assessment in the course

Students are expected to participate actively, and their individual work, participation in discussions, and teamwork is assessed accordingly. Each team member is evaluated with the same assessment metrics: rubrics, according to the several outcomes. The example of the rubric for assessing teamwork is in the Table 4.

Table 4. Rubric for assessing teamwork

	Below expectations 0-1 point	**Meets expectations 2-3 points**	**Exceeds expectations 4-5 points**	**Points**
Organization and participating within the team	Students are not well organized; He/she doesn't collaborate and share ideas. They don't know how to manage the time and distribute the task within the group.	Students are well organized most of time; He/she usually collaborate and share ideas. They often know how to manage the time and distribute the task within the group.	Students are well organized within; He/she collaborates and shares ideas. They successfully manage the time and distribute the task within the group.	
Collaborate decision making regarding methodology	Student doesn't discuss the methodology for the task. His/her method is individual and not appropriate for teamwork.	Student usually discusses the methodology for the task. His/her method is appropriate for teamwork, but the performance is not very good.	Student communicates and discusses the methodology for the task. His/her method is appropriate for teamwork and well adjusted to specific task.	
Collaborate decision making regarding data	Student doesn't agree on data. He/she is not sure whether the presented results are correct and doesn't want to comment on them.	Student most of the time agrees on data. He/she is usually sure about the presented results and often wants to comment on them.	Student agrees on data. He/she is sure about the correctness of the presented results, and critically comments on them.	
Professionalism and attitude towards the task	Student doesn't act professionally and has excuses for bad performance. T he group has the negative attitude about the task.	Student usually acts professionally and his/her performance is acceptable. Student has a positive attitude about the task.	Student acts professionally and his/her performance is on high level. The student is motivated and shows advanced knowledge on the task.	
			Total scoring	

Active participation requires commitment to adding value in a group work and in class. This refers to a group project of the creation of the business report at the very end of the course through which the participant show to what extent they analyze results of some 15 market research projects, make marketing decisions based on available data, analyze result of their decisions and make necessary changes in their marketing plans (or strategies). Business results of the group are also taking into account. In addition to that, grades are given for the consistency of the marketing strategy and its long term perspective. At the end students analyze their complete work and prepare business report and final presentation where each student needs to present part of the plan. This is also used to evaluate communications outcomes. Besides that, the students complete six examinations covering the course content. The business competencies and the integration of analytical and critical thinking

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outcomes are evaluated in both oral presentations and written report. Evaluations are guided by rubrics that have been developed for assessing each outcome. A summary of these assessments and the student feedback create the final grades.
How grades are often not sufficient indicator of knowledge it is important to use rubrics to have more detailed information on what exactly and to what extent has each student mastered. By adding numbers of categories in rubrics it is easier to get information on which part of the certain goal (leaning outcome) does student needs to improve. It is professor's expectation that students will rise to the challenge and meet or exceed the established earning goals. However, if some students fail in doing so, this assessment will prove valuable. For example, in the first two cycles of measurement we assessed four goals of our course: knowledge; critical /analytical skills; communication skills and teamwork; and use of new technologies, and feedback was used to gain insight into the nature of factors that limit the students, identify potential paths for improvement, and enhance learning opportunities for the students. We will describe some actions and improvements.

4.3. Assessment of knowledge

The assessment of cognitive outcomes was provided with objective methods: multiple choice test questions [10]. At the beginning there were two tests covering the course content in 11 parts, and the results were unacceptable. Specifically, results show that more in-class time should be allocated to five parts: brands, marketing objectives, production, customer's perceptions, and R&D. Particularly, students should get more detailed instructions related to these areas during the simulation. Also, an overview of these areas could be given before the simulation starts. The necessary changes were done and implemented in the syllabus. Instead of only two, four additional tests were introduced so theory is now covered with 6 tests.

4.4. Assessment of critical / analytical skills

In the same year, there was some concern that students were not meeting desired level of critical / analytical abilities. To assess those abilities it was measured how students were using appropriate tools in situation analysis, how they identify the problem and multidisciplinary approach, how they understand other perspectives and the facts, how they analyze the quality of evidence, apply strategic tools and financial analysis, generate alternatives, and conduct a thorough business judgment. As an improvement, some parts of the course were adjusted to better teach the students how to use a multidisciplinary approach to the problem and to incorporate financial indicators into the case analysis.

4.5. Assessment of communication skills and teamwork

The communication skills were rated as acceptable already in the first two cycles when individual presentation, (oral) skills, and written skills were assessed, while teamwork skills were just partially acceptable, with good performance in: listening, persuading, questioning, and respecting. In the field of teamwork, the report highlighted several issues: students indicated the natural tendency to concentrate in his or her area of expertise, which is not a problem itself, but if there are few students whose expertise is promotion and no one in the team is good in finance, then this becomes a problem. Another issue came later in the simulation, when everybody had a common understanding of the strategic issues but the management of the firm became more complex in terms of number of brands. Some conflicts within the teams could be observed, but these were resolved quickly. Thus, monitoring the work of each team and helping them in overcoming their internal issues was necessary. Overall objective was to improve in the future some aspects of working in teams, especially helping, participating, and sharing. At the beginning, all course sessions were conducted in the class, but later online lectures were introduced in a form of distance learning, which required new approach to teamwork, especially the role of team leader, in order to build its weakest aspects.

4.6. Assessment of use of new technologies

Relating to the use of new modern technologies was also measured, and then analyzed trough some aspects of working in the computer lab, and also at home, throughout distance learning on the MarkStrat simulation. Students were trained to enter, search, and analyze new data (product-related, segment-related, distribution-related, and financial data), search the results of market research, and use the data to create final report and Power Point presentation (see the Table 5).

Table 5. Rubric for the goal new technologies

	Below expectations 0-1 point	Meets expectations 2-3 points	Exceeds expectations 4-5 points	Points
Students will know how to search for different types of data.	Student doesn't know how to search for data or does it incorrectly.	Student does it correctly, but with some difficulties and mistakes.	Student does it correctly and without difficulties.	
Students will know how to enter different types of data.	Student doesn't know how to enter data or does it incorrectly.	Student does it correctly, but with some difficulties and mistakes.	Student does it correctly and without difficulties.	
Students will be able to interpret and analyze the data.	Student doesn't know how to interpret and analyze the data or does it incorrectly.	Student does it correctly, but with some difficulties and mistakes.	Student does it correctly and without difficulties.	
Students will know how to appropriately transfer the data into the final presentation.	Student doesn't know how to appropriately transfer the data or does it incorrectly.	Student does it correctly, but with some difficulties and mistakes.	Student does it correctly and without difficulties.	
			Total scoring	

As students showed underperformance in the first two rounds of measurements, but also in the upcoming round, this was the area of most intense work. Preparatory session at the beginning of the course was introduced in order to clarify the importance of using simulation handbook. Search for different types of data was associated with lack of knowledge so students were encouraged to prepare for classes in detail and regularly solve online tests. This helped them to find their way in the simulation. Additional presentations and instructions were posted on Blackboard so students can access it anytime and anywhere. From these materials the students could learn at home. Last measurement in the academic year 2013/2014 showed improvement in student's performance. That measurement will be explained in details to present the way of measurement.

Assessment metric was rubrics with trait used to identify performance level of each student. Student's performance was analyzed upon the four criteria (see the Table 5). They could minimally score zero, and maximally 5 points on each trait. Their performance is evaluated as below expectations (BE) if they scored 0-1 points; if they scored 2-3 points they were considered to meet expectations (ME); while if they scored 4-5 points they exceeded the expectation (EE). The sum of their score on each trait gave their overall score for the measured goal. The distribution of score is as follows: 0-13 points = below expectations; 14-17 points = meets expectations; 18-20 points = exceeds expectations. Expectations were: 20% of students in BE category; 40% of students in ME category, and 40% of students in EE category.

Table 6. Summary of results

MBA Marketing							
AOL: New Technology							
#	SURNAME & NAME	C1	C2	C3	C4	SUM	
MBA Marketing		Students will know how to search for different types of data	Students will know how to enter different types of data	Students will be able to interpret and analyze the data	Students will know how to appropriately transfer the data into the final presentation	Points	Expectations (BE, ME, EE)
1	B.M.	4	4	3	4	15	ME
2	B. B.	5	5	5	5	20	EE
3	B. N.	4	4	4	4	16	ME
4	H.B.	5	4	4	5	18	EE
5	I. F.	3	3	4	5	15	ME
6	J. V.	5	5	5	5	20	EE
7	J. Z.	3	4	3	4	14	ME
8	K. A.	4	3	3	4	14	ME
9	K. I.	3	4	3	4	14	ME
10	M. Mo.	5	5	4	5	19	EE
11	M. D.	5	5	4	5	19	EE
12	M. Ma.	3	3	3	4	13	BE
13	P. O.	5	5	4	5	19	EE
14	R. L.	3	4	3	4	14	ME
15	S. H.	5	4	4	5	18	EE
		4,13	4,13	3,73	4,53		

SUMMARY OF RESULTS			
category	BE	ME	EE
condition	0-13	14-17	18-20
# of students in the cate	1	7	7
percentage	6,67%	46,67%	46,67%

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Total of 15 (100%) of students participated in this individual assessment. Student's use of new technologies was observed throughout the several weeks of classes. Summary of the results (Table 6) shows that only one student's performance was below expectations (in percentage only 6.7%). On the other hand, there was an even distribution of student in categories "expectations met" (46.7%) and "expectations exceeded" (46.7%).

5. Conclusion

Assurance of learning is an important project at the Zagreb School of Economics and Management, which is able to assess learning outcomes that contribute to achieve goals and objective derived from mission. It also allows quantifying the very level to which students underperformed, meet the expectation or exceeded them according to every objective. For the MBA course of "Marketing simulation-MarkStrat", which case was presented in this paper, this is especially important due to complexity of the course that involves technology (simulation) with both traditional and new ways of learning (especially distance learning). The case presented shows that using assurance of learning methods and instruments, learning outcomes are achieved more efficiently which enables the whole class environment to become more effective in acquiring knowledge and skills, that according to the mission statement they need in ever-changing globalized world.

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Professionalism and Ethics in Engineering Education and Research:
Issues of Skills Development and Future Employability

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Abstract

In preparing students for today's employment, in addition to their technical and digital skills, there is a need for them to understand and develop professional skills. Students should be made aware of the role of their appropriate professional body, and be encouraged to become involved with its activities. All of the professional bodies have a Code of Conduct, which can be used to discuss professional practice. Various mini case studies to illustrate this will be included in the paper, which can and have been, adapted to students on different technical courses. Examples from the news can be used to further illustrate both ethical and legal issues, as students need to be aware of these both for their own sake and that of their employer's. Examples are given in the paper. In addition, the need to develop the softer skills, particularly presentation skills, that are so important to the initial employability and future promotion of students, are discussed. The issues of linking presentations with other topics, to overcome the reluctance of students, are reported. These include students working in small teams and with weekly feedbacks by one member of the team in turn; providing confidential feedback of presentation style. The understanding of these professional skills is not only important for the students' future employer, but also for their own employability and their future life.

Keywords: *Professional Bodies, Ethical and Legal Issues, Soft Skills*

1. Introduction

The need to prepare students centrally for employability throughout their working lives is a major aspect of education. In addition to being able to cope with the constantly changing technologies, they will be confronted with various ethical issues. The majority of technical degree courses in the UK include either a dedicated unit on professional issues or proof that the topics of that unit are embedded within different aspects of the course. To date this unit also normally addresses skills needed for employability, such as preparation of CV and presentation skills.

In order that a university can achieve accredited status by their professional body, an inspection team from that institution, (such as the IET or the BCS, The Chartered Institute for IT) would examine the syllabus, specifications of the assignments, also normally discuss how the various elements associated with professional issues are addressed both with the relevant staff and separately with the students.

Regardless of how initially, well designed and organised a course would be, it would not have become accredited by the professional body unless it was seen to provide adequate coverage and normal assessment associated with professional issues.

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In order for a course to remain accredited, it would have to again be re-examined, usually every five years, or when a major change in the content or correction of the course takes place and to prove that the professional issues is still adequately covered.

2. Content

The content of professional issues unit normally involves ethical issues, including knowledge and understanding of the appropriate Code of Conduct of the accrediting institution, legal issues and skills relevant to employability. In a recent study involving the use of a personal report of communication apprehension (PRCA) instrument for measurement of students soft skills. It was found that students realised the need to enhance their soft skills in order to have a competitive advantage when seeking employment [1]. The two specific skills identified were team skills and interpersonal skills. Results of the study showed no significant difference between the attitudes of male and female learners. Even in the case of PhD which is seen as an important training for future scientists, followed by postdoctoral fellowship period, key issues relating to employability beyond academic institutions into industry and public sectors are vital [2]. This has resulted in changes in the nature of programmes offered relating to specialisation and breadth. In the final stages career planning and structures are considered for entry into employed as an independent fulfilled scientist.

2.1. Employment Skills

These skills would normally be presentation skills, preparing a CV, understanding the process of applying for a position, producing a covering letter and preparing themselves for interviews. The manner in which these are taught varies slightly for different courses. An example of the process, at Southampton Solent University, is as follows. The students, working normally in small teams of three or four, would examine the Internet and other sources, to identify jobs suitable for their degree course, and then if possible, draw down the relevant supportive information about one of the jobs. This would include further details of the qualifications, skills and experience expected, possibly details of the type of work to be undertaken by a successful candidates, and relevant information about the organisation.

One member from each team would stand up, and briefly describe the findings of that team, including where the job was originally advertised. This encourages confidence in informal presentations, and it also makes all the students aware of different sources and content for future employment.

This theme is continued by asking each student to produce a two side A4 CV. This would include details of their skills, their education, qualifications with the most recent, being probably their previous year's results on the course, at the top of the list. It would also include any work experience relevant to the nature of their course, and then any other experience, such as working part-time in a supermarket and also including any unpaid voluntary work, giving details, dates and length of involvement. In addition there would be a section on their hobbies or sport. This can be extremely useful for a potential employer such as:
A team sport, indicating team working ability;
Team captain, indicating potential leadership and management skills;
Representing the university, college or school, implying self-motivation to reach that level and reliability;
Achieving Awards or prizes, could imply in addition a competitive inclination.

The CVs were exchanged between the members of the team for comment and suggested improvement. The enhanced version of the CVs were then commented on by the lecturer, taking account of not only of content but layout and appearance of the CV, with feedback given to the student. As a further exercise, the students in each team constructed a fictitious job, together with the supportive "further information" and each member, from a different team, individually applied for each of the jobs of the other team, modifying their CV to suit, such as changing the order or emphasis, and also providing an application letter for each of the jobs. The first team would then read the letters and applications, decide on to typical interview questions, and interview each of the "candidates".

By the completion of this exercise, across several weeks, all students would have been "interviewed for a job" and have interviewed other students. The lecturer would sit in on some of the interviews, and after discussing alternative answers to some of the questions, when the students had not provided the answers in the most effective way.

2.2. Legal Issues

At Southampton Solent University, various computing programmes are undertaken, ranging from software engineering, networking, web design, business IT and games development. The elements of the professional issues unit are modified to provide relevant examples for the different computing programmes. The topics on legal issues included:

Data Protection, and included the differences with the American legislation and those of another country such as India;

- Computer Misuse including issues involving hacking and creation of viruses;
- Copyright, particularly relevant to the computer games industry;
- WEEE, consisting of disposal of Waste of Electrical and Electronic Equipment relating to green issues and potential legislation in that area;
- Ergonomics and Health and Safety legislation.

Throughout the various topics, the means to encourage the correct, ethical attitudes were discussed. For instance, the students in the teams produced posters to illustrate key issues, such as with Health and Safety and with ergonomics. One member of each team would stand up in front of all the students with the poster or the e-poster, to describe the key points of the poster.

For each activity, a different member of each team would be making the formal or informal presentation, so their confidence was gradually increased. This was felt to be important, as many employers often require candidates to make a presentation, in addition to interviewing and possibly other tests. When the different legal topics considered, these students were encouraged to identify recent case histories when the law was broken, and also the difference in the penalties imposed from different countries. These were also reported back to all the groups by a member from each team.

2.3. Ethical Issues

A series of mini case studies were used to illustrate different situations, leading to discussions, by the teams of the impact on the individual, on the employer and also on wider society, with feedback provided by a member of each team.

The students were encouraged to identify from the Internet, actual case histories which were presented by a team member to the group. In addition, the teams developed fictitious case studies relevant to their future area of employment, with informal presentations made, as before by a member of each team, relating the case study to the relevant elements in the BCS's Code of Conduct. This Code was chosen, as the courses were accredited by the BCS. A selection of mini case studies follows:

You work for a consultancy firm, which is also an agent for a major software supplier. You realise that your firm is recommending, and also purchasing this supplier's software, for their clients. The clients are unaware of the link between the two parts of your consultancy firm.

A contract requires an experienced Web designer to develop an e-business system. You have just been awarded the contract but you failed to mention that your sole knowledge was second-hand and that you had not worked on an e-business system before.

While working for FinCo you were surprised and delighted to discover, by examining their systems specification, that there is going to be a merger of that company so you have decided to purchase shares.

A supermarket is concerned about its reputation and its liability, with respect to any potential problems associated with personal data relating to the staff or customers (including online customers), both currently and in the future. Indicate briefly, in order of priority, (the first being in your view the most critical for the supermarket) the issues related to personal data that you feel could make the supermarket liable to prosecution or litigation, currently or in the near future. Justify your choice.

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Students were also given case studies, where the different teams considered the ethical dilemmas from different perspectives. An example of this is considering a "wicket" employee of a software house creating a "hidden" access to a system. The possible options and the various outcomes of these actions would be considered, from the viewpoint of the friend of the "wicked" employee who discovered this; of the direct manager of the "wicked" employee; of the senior management of the company; of the shareholders and of the clients of the company. Presentations were made from each of the teams, from their allocated perspective, leading to general discussions. This scenario is then changed to indicate that the justification provided by the "wicked" employee was for the purpose of whistle-blowing, possibly to "right a wrong". This led naturally to a series of case histories and of case studies in emergency situations when the correct action is more difficult to identify. An example of this would be for a 24 times 7 trading company, when a certain procedures might not be followed in order to be able to "re-start" the activities of the company very quickly. In this type of situation, the students consider the actions they would recommend during and after the "non-standard" procedures.

With the ethical case studies, the students were encouraged to discuss their own possible actions, and for each of these actions, what the outcomes could be on their own future careers.

3. Assessment

One of be assessments of a professional issues unit at Southampton Solent University was to encourage each student to develop a portfolio of their activities each week. Part of their portfolio would have been provided by the team, but there would be individual elements that would be sorely produced by the student. The portfolio would be submitted, with particular elements identified. :

- (A) produce case histories (real or synthesised) of maximum length one side each, together a brief explanation (one side each) for
    - DDA [Disability Discrimination Act],
    - WEEE – [waste of electrical and electronic equipment],
    - legislation related to ergonomics and the use of computers.
- Each of the 3 case histories must be related to the relevant piece of legislation, and related to the computing industry or the use of computers. Include three references for each piece of legislation, at least one of which should be a web reference and at least one a non-web reference. Reflect on the ethical and social implications of the legislation from the point of view of a graduate from your degree course, and also from the view point of their employer.

- (B) produce 2 case histories (real or imaginary) of minimum length half a page each, and maximum length one side each, together with a learning activity, and an explanation of the correct solution to each of the learning activities, associated with each one, . Each case history must be related to a different element of the BCS Code of Conduct, which you must clearly identify in each case. The case histories must be relevant to computing or its use and be appropriate to your degree course. Produce for each case study, an appropriate power point presentation, together with the speaker’s notes as a text explanation of each screen, which should include as well as the case study, the relevant element of the Code of Conduct, the learning activity, the solution and explanation of the solution.

- (C) produce your cv, of two sides A4, including a passport size photograph on the top right-hand corner of your word document. Include details of your level 2 (and if appropriate level 1) units including your separate results for each unit. Separate out relevant experience (if appropriate) and other experience, and include Interests and other relevant information. Take care with the layout and the order of the sections of your 2 page cv.

This provided a framework for the assessment criteria as shown in table 1. It has to be noted that all the criteria have the same weighting, and cover the learning outcomes

TABLE 1: ASSESSMENT FRAMEWORK CRITERIA

Third (40 – 49%)	**Lower Second** (50–59%)	**Upper Second** (60 – 69%)	**First** (70% and above)
Able to recognise the basic skills and knowledge developed from a learning experience	Able to recognise the skills and knowledge developed from a learning experience and relate this to evidence from the Appendices	Able to integrate learning from individual activities into a coherent whole	Able to reflect fully on own learning
Presentation of the assignment but with poor structure.	Structured presentation of the assignment with limited additional material.	Clear, well structured assignment.	Clear evidence of ability to produce the assignment to a professional standard.
Limited participation in task in Appendix A – of 3 legal case studies etc	Reasonable participation in task in Appendix A	Good participation in task in Appendix A	Very good participation in task in Appendix A
Limited participation in task in Appendix B – 2 ethical case studies, different learning activities, with solutions, and power point material	Reasonable participation in task in Appendix B	Good participation in task in Appendix B	Very good participation in task in Appendix B
Limited participation in task in Appendix C – cv as specified	Reasonable participation in task in Appendix C	Good participation in task in Appendix C	Very good participation in task in Appendix C

4. Higher Education Curriculum Relevance and Employability

As a result of multiple pressures sparked off by economic crisis in the mid-seventies and in recent years from 2008 till now, leading to budget cuts, austerity and financial stringency, there seems to be a move of power and authority away from departments to faculty or even institutional level, that is from the periphery to the centre. The voice of students in programmes development and course provision are seen to be no more successful than the voice of employers. The potential is recognised for conflict between the concerns of higher education teaching staff concerns to induce critical perspective based on research and speculative enquiry and the need to adapt to employment requirements. However the direction remains unclear [3].

There is the need to carry out a thorough reorganization of the curriculum on an interdisciplinary basis, focusing on particular areas of study, field problems, and historical periods. Through these and the use of diverse tools, methodologies and theoretical models higher education could combine students' curiosity and the priorities of researchers and teaching staff with appropriate relevance to the content of their future work. Universities would have to move away from post-school school mentality, towards research and align itself to knowledge creation that is informed by research and best practice fit for the world of work aimed at improving lives of individuals and society.

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5. Generic Skills and Technical Learners

We live in a world that where progress, wellbeing and sustainable development of individuals, businesses and society in general depends on the knowledge economy, which is itself dependent on human capital. In this era of globalization, employers everywhere expect educational institutions to produce skilled graduates required by the employment market without additional training. The higher education sector plays an important in providing human capital for achieving knowledge economy and meeting the demand of the industry. There is the concern of most employers today about the generic skills which should be mastered by graduates to enable them fulfill their effective roles as they embark in the world of work which requires not only technical but generic skills. It has been reported that a major challenge today is that in order to continue to prosper in a global economy, individuals are expected to have well-developed technical skills, as well as generic skills that allow high levels of flexibility and adaptability and an ability to work across a range of jobs[4].

Studies have identified skills needed in the workforce and it has been revealed that 75% of the eight domains of competencies to which higher education providers should be placing more emphasis refers to generic skills. These generic skills comprise Basic skills [5, 6, 7, 8], Working in team skills [7, 8, 9, 10], Thinking skills [6, 8], Problem solving skills [5, 7], Personal qualities [6, 7, 8, 9],Technological skills [8, 9], Information management skills [7, 8], Entrepreneurship skills [10],Leadership skills [7], and Lifelong learning skills [6]. Leadership and entrepreneurial skills are areas least developed for technical students. They remain areas of concern where efforts should be directed at improvement. Over the past ten years at Ulster University at the postgraduate level modules in work based learning, entrepreneurship and innovation have been delivered as core modules in the Master's degree programme in Engineering with specialism. This has been well received with positive feedback from both students and employers who have seen and experienced vast improvements in their skills for work. Skills in entrepreneurship enable and empower the ability to explore and discover new opportunities, the willingness to take risks and the enthusiasm for the individual to try out new methods or ideas [11]. It is one of those skills that drives the learner to aspire to being an employer instead of being an employee after education and training.

6. Changes in the Sectors and Individual Competences

Employee competences are critical to the adoption of technological and organizational changes and to the development of the necessary innovation capabilities in any organisation. Although studies involving the analysis of competence and skill development have identified gaps between education and practice, environmental dynamics have always been taken as fixed and there is the continuous revelation of current demand for competence [12, 13, 14, 15, 16].

Technological and market changes leads to disruption of several sectors which impact on business and is shaped by employees. The future needs a workforce of people that are organized and can handle and make use of technologies to serve and meet customers needs [17, 18, 19]. Digital innovation affects not only production technologies and production processes, but also the components and devices, interfaces, platforms, and user scenarios [20, 21]. The impact of changes continue on individual competencies continue to evolve as society and the sectors evolve too.

7. Conclusion

In getting fit for practice, it is important that the graduates of today are knowledgeable and skilled for the workforce, that is, fit for practice. The knowledge economy can only make progress if all those employed are equipped with the right knowledge and are skilled. In our present work, we have identified that there is the need to strengthen competency development within higher education. This has implications for future research and curriculum improvement in engineering and allied subjects. In order for engineering education to serve the individuals and organizations in society Issues of professionalism and ethics must be addressed having a professional curriculum of study in which issues of skills development and future employability of the learner is robustly from the perspectives of the profession and discipline areas, which have influenced its evolution. It is important that the fundamental concepts of value, relevance and capability be used to identify key industry requirements at the beginning of a career and to examine how well students respond to them. This should help provide focus for programmes of key competencies needed for career success [22, 23]. Employers and graduates from a wide range of different industries could be involved in the development of particular study programmes utilizing a step-by-step industry-driven approach.

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A pragmatic teaching methodology in a final year module in Engineering Education

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Abstract

Teaching can simply be referred to as an act, practice or an exercise of exchanging ideas or principles usually by an authority unto the person(s) being taught. The author believes that teaching can also be referred to as the process of imparting knowledge and skills to students or learners. This process may involve the activity of educating and instructing which often time has a formative effect on the mind, character and physical ability of a learner. For this act to be effective, it is expected that a teacher will employ pragmatic teaching methods to drive his/her point home to ensure that the students acquire the requisite learning and thereby imparting the lives of the learner at the long run. This paper reports some pragmatic teaching practices that have been employed in teaching a final year module course in an Engineering Faculty in South Africa. In addition, the feedbacks on how the students felt about the teaching methodologies employed were received and analysed to further improve the teaching practices employed. Some of the teaching methods introduced to the students over a period of time include the use of relevant PowerPoint slides, video, industrial visits, show casing of prototypes in class, brainstorming sessions in class and once in a while have a class in a relaxed atmosphere for example under a tree with a good shade. From the feedbacks received from the unanimous teaching evaluation questionnaires analysed, it was revealed that all the students either agreed or strongly agreed that the teaching and learning materials and the methods employed have supported and facilitated learning in the module during the course of the semester.

Keywords: *Engineering Education, Final year Engineering module, Pragmatic, Teaching practices/methods*

1. Introduction

The highlight on improving engineering module teaching methodologies is due to recent complaints from the industrial sector in many developing countries especially in Sub-Saharan Africa on engineering graduates who lack applicable practical skills, exhibit low level of confidence and technical know-how of the recent cutting edge technology [1]. This has increased considerably the level of unemployed graduates, increased the cost of hiring and re-training, negatively impacted the economics of many industries and also the gross domestic product (GDP) of the countries affected [2]. These problems are more pronounced in very poor countries with inadequate infrastructure, teaching and learning aid, power, information communication technology (ICT), over population of classrooms and lack of a functional engineering workshops [1]. In places where these inadequacies have been overcome and students still do not effectively grasp the fundamental knowledge for practical applications, a background check on pre-university education, reassessment of the curriculum to meet industry demand and improving the teaching methodology is of utmost importance. This will reduce the widening gap of knowledge between an academic engineer and an industry engineer. Infusing the later into the former will create a balance and a convergence point for industry and the university. The re-assessment of teaching curriculum must cater for all genre and social class of students and also satisfy the demand of the community/industry. Pre-university problems have been highlighted mainly as due to poor mathematical, scientific and technological foundation knowledge upon which engineering principles are built [1, 2]. According to Fink, et al. [3] a curriculum that is all encompassing must; expose engineering students to early experiential activities while in school; cut-across various relevant disciplines; accommodate different learning methodologies; encourage explicit skills improvement for effectiveness; showcase the impact of engineering decision on sustainability; systemic; project management and incorporate ethics. From time immemorial, knowledge has been passed through teaching. Teaching and learning is a dynamic approach in which the sequence of thought and reasoning of a person is changed in a particular field. In simpler terms, teaching is an act, practice or exercise that involves the exchange of ideas and principles within a field of knowledge usually by an authority unto the person(s) being taught. Teaching methodologies keep evolving along social, economic and technological advancement [4]. This assertion is also true for engineering education in higher institution of learning in South Africa as they desire to be more competitive in practical sciences and technology on a global

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scale. Teaching of engineering modules for effective learning goes beyond preparation and presentation rather more on reassessment of the impact of the knowledge shared. Between preparation and presentation, the loop of continuous review of course content and reformulation to suit the advancement of engineering and organization to deliver a more cognitive skill set is required. The quality of the delivery of engineering education in the country is monitored by the Engineering Council of South Africa (ECSA) through accreditation visits to institutions of higher education across the country. However, it is expected that after the presentation of modules, there is a need to re-evaluate if the teaching outcomes have been met. This is achieved through student assessments and teacher observation to verify if the knowledge has been adequately communicated. This teaching cycle is as summarised in Figure 1 [4].

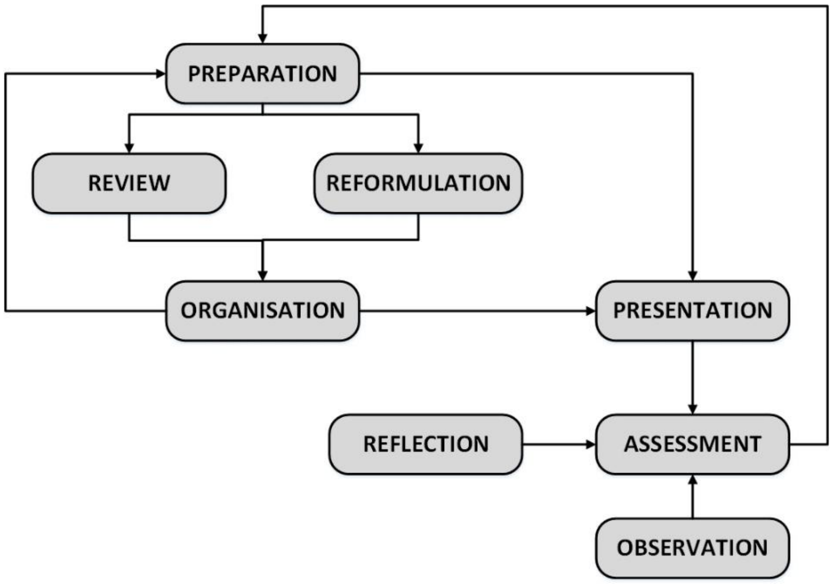

Figure 1. The teaching cycle

To improve the employability level and industry acceptance of engineering graduates, universities need to deliver their course contents in best way possible. Good course content delivery can enhance the satisfactory levels of the students and the graduates [5, 6]. Many universities are exploring better ways to deliver their primary assignment, teaching and research, through constant evaluation of the teacher's performance. The teaching and the module evaluation is a key index performance tool which is necessary for teacher's self-reflection, professional development and to maintain the university academic achievements and remain competitive [7]. The ability of a teacher to effectively deliver an engineering module depends partly on the nature of the school environment including all deplorable teaching aids, ICT and the teacher's sense of efficacy [8]. Due to classroom diversity, distribution of students, and varying degree of conceptualization and understanding of the course contents, a singular teaching methodology might not be best suited for all students [9]. However, a blend of innovative teaching methodologies must encourage deep learning with support for independent learning, appropriate learning activities, encourage interaction with others while simultaneously improving the communication skills and self-confidence and use of appropriate assessment techniques. The advancement of ICT has opened a new channel where teaching module can be adequately delivered in a much more practical sense than the conventional method. This of course adds to the cost of teaching and due to spending limits, many public funded universities have not fully deployed ICT in their teaching approach. In the Faculty of Engineering and the Built Environment where the author teaches, ICT has been fully deployed to enhance student's understanding of engineering concepts. Due to the increasing level of interest from government parastatals, research funding agencies and the industries, the level of alertness for skilled engineering graduates has been heightened, with emphasis on improving teaching methodologies. As engineers are needed in all facets of problem solving and economic advancement of a country, their skill set must be adapted to localised problem solving with an international exposure. Improving on the skill set has been pragmatically approached by providing a dynamic teaching methodologies to accommodate almost all classes of students at the University. Power-point presentations and MS Excel has been employed for teaching and iterative calculations while modelling and simulation software like MATLAB, Autodesk AutoCAD and Solid works to mention a few, are available for students use. Video presentations have also been used to explain abstract concepts and theories. The use of customised tablets for direct access to the library e-book materials has also been implemented. Worthy to be mentioned, is the University's blackboard, an online web-based platform for teaching and assessment. Access to hands-on practical with updated machineries are encouraged in various

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modules as required. Also, collaboration with sister universities and industries are also encouraged to ensure that the students are exposed to a wide learning environment. Also, informal teaching in a more relaxed environment has been employed to increase the student-teacher interaction. To this end, this paper presents a quick assessment of all the teaching methodologies employed for teaching a final year module to engineering students with a view to improve the academic and the industrial expectations from the students. The evaluations were independently conducted by the tutors assigned to this module.

2. Methodology

2.1. Participants

The participants for this evaluation are final year students of an Engineering Faculty in a University in South Africa. The students that participated in this evaluation attended between 80-100% of the lectures for the course. 67 students registered for the course but only 48 students responded to all the questions in the questionnaire.

2.2. Data collection procedures

Personnel in the Centre for Professional Academic Staff Development at the University in collaboration with the lecturer designed the teaching and the module evaluation questionnaires. The questions were structured using a five point Likert scale (Not applicable (0), Strongly disagree (1), Disagree (2), Agree (3) and Strongly disagree (4)) and were used to obtain the opinions of the survey participants in relation to the teaching style of the author and also the overall delivery of the module. An open ended was also included to allow the participants freely express their opinions. The evaluation questionnaires were distributed to student during a contact session for the module. The questionnaire was designed to gather feedback from the students regarding certain aspects of the teaching, learning and assessment. The evaluation questionnaire is divided into two parts; teaching evaluation methodology with 14 mandatory quantitative questions, one qualitative and a maximum of 12 additional quantitative questions as selected by the lecturer; and the course module content was evaluated with 13 mandatory quantitative questions, one qualitative and a maximum of 13 additional quantitative questions as selected by the lecturer.

3. Results

The mandatory teaching evaluation results for the 2014 academic session is as presented in the clustered bar chart on Figure 2. The data analysis on question 13 not included in the bar-chart reported the percentage of class attendance by the students who responded to the questionnaire. It was observed that 97.87% of the students attended all lectures. From the Figure, 35% agreed strongly and 58% agreed to the effectiveness of the teaching methodologies employed by the lecturer. 2% of the students did not find any of the question applicable.

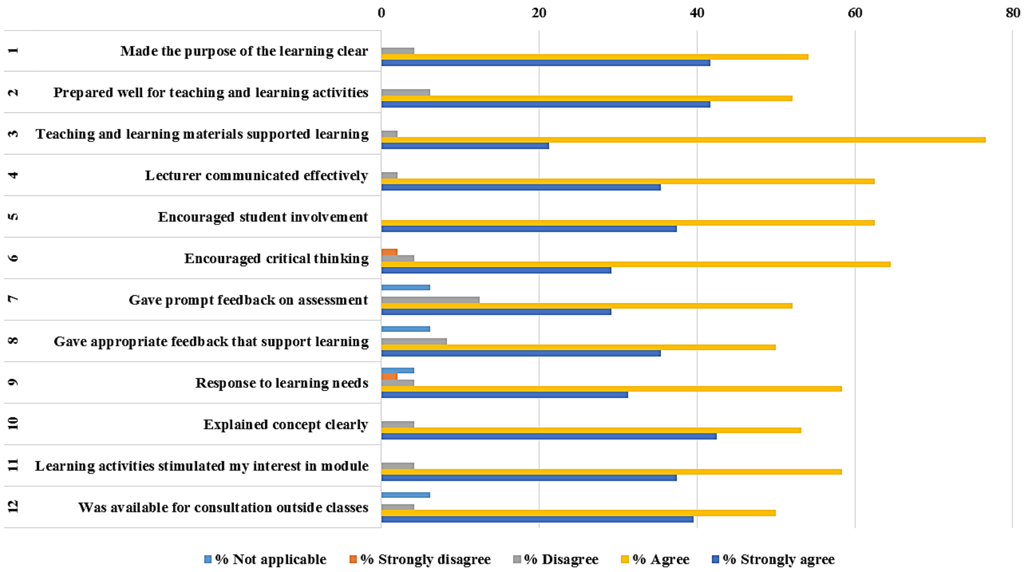

Figure 2. Clustered bar-chart on the mandatory teacher evaluation for 2014

The students' responses on the additional questions on the teaching evaluation further confirmed their satisfactory acceptance of the teaching methodologies of the author. 41% agreed strongly and 51% agreed while 8% either reported not applicable or disagree with the teaching methodology. The distribution of their responses in as presented in Figure 3.

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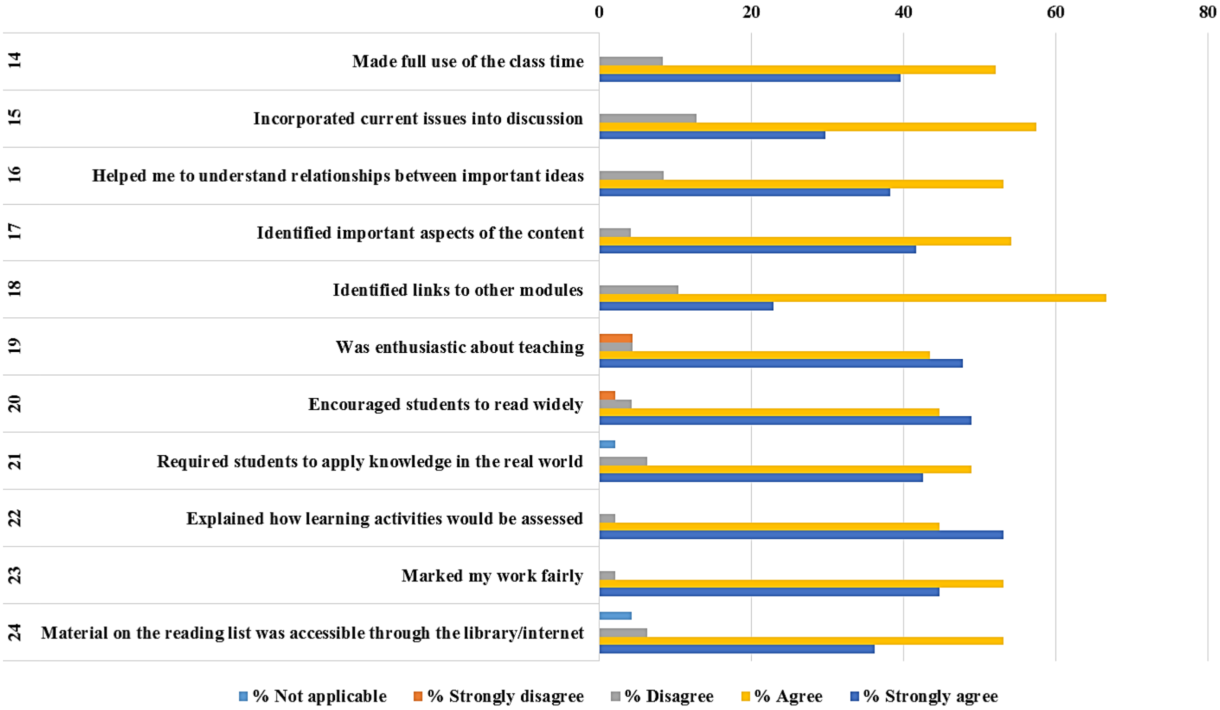

Figure 3. Additional questions on teaching evaluation for 2014

On the overall, the results and the feedback of the teaching evaluation viewed and interpreted in relation to the overall response rate of the survey revealed that the teacher scored above 3,2 out of 4 point for every question in the questionnaire and there was none that had a mean score less than 3,2. Nonetheless, the author believes that there is always a room for innovation and improvement in her teaching skills.

The students' responses on the course module contents (the module evaluation) was also analysed and the results are presented in Figure 4. 33% of the students strongly agree with the course module contents and appropriate and 54% only agreed.10% of the student disagreed with some aspect of the module content. On the additional questions in course content module evaluation, the result were similar to the mandatory questions. 32% of the students agreed strongly, 60% only agreed and 7% disagreed.

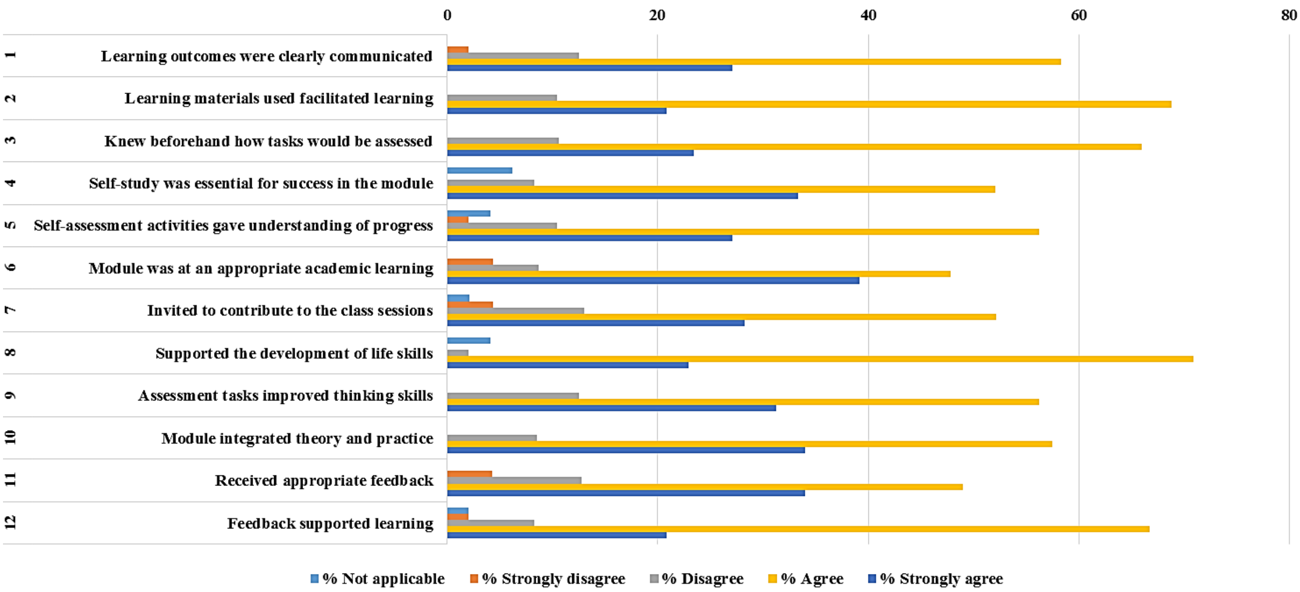

Figure 4. Clustered bar-chart for mandatory questions for module evaluation for 2014

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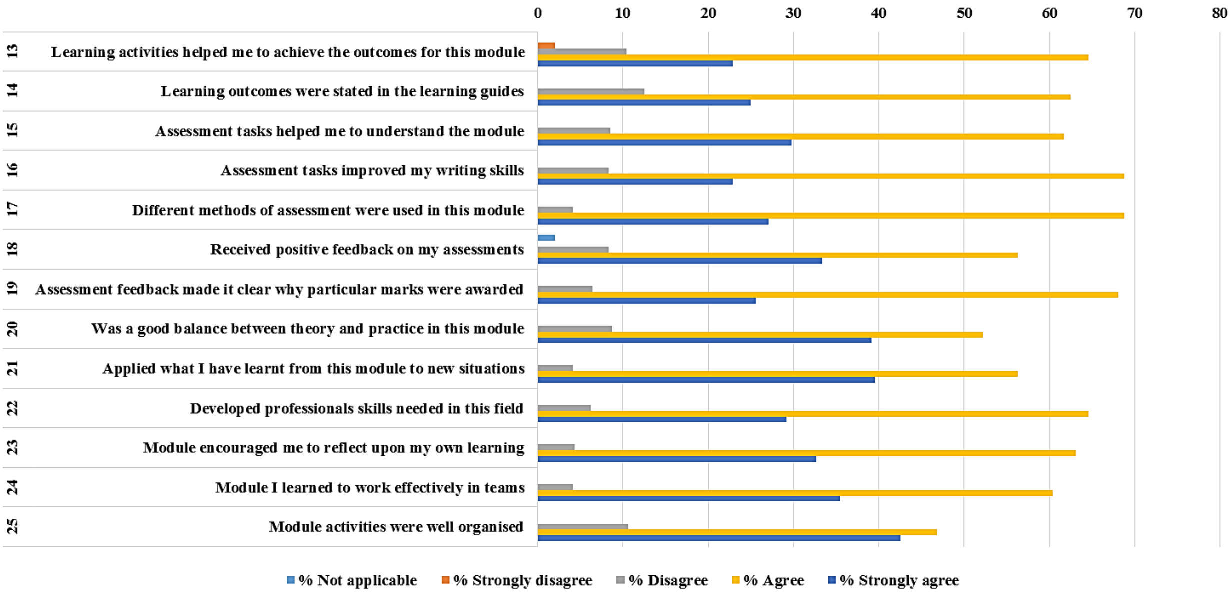

Figure 5. Additional selected questions on module evaluation for 2014

On the overall, the results and the feedback of the module evaluation viewed and interpreted in relation to the overall response rate of the survey revealed a mean score above 3,2 out of 4 point for every question in the questionnaire except the question on how tutorials were organised which had a mean score less than 3,2. This feedback has been reviewed and more tutorial classes have been organised in the 2015 academic session for this module.

4. Discussion

The author has consciously ensured that all her students have the privilege of experiencing a balanced learning process in innovative ways. She regularly supports her teaching with relevant PowerPoint slides, videos; industrial visits, show prototypes in class and once in a while have a class in a relaxed atmosphere under a shaded tree. The author recognises and enjoys the good student-teacher relationship that exists between her and her students. Learning experiences have always been exciting to her students and the students always feel free to share personal issues with her and she enjoys discussing such issues with the students. From time to time, the applicant encourages and motivates the students.

The analyses of the responses of the students to the questionnaires revealed that the students either *agree* or *strongly agree* to the points being assessed both about the teacher, the delivery of the module and the design of the module contents except in very few exceptional cases. The author believes that this is a true reflection of the effectiveness of the teaching pedagogies employed in this module. With respect to the teaching evaluation, some of the responses to the open ended question on comments about the teacher include "*Learning was fun*", "*The teaching was great, no complaints*", "*Videos, trips, teaching – all these were done to add to m learning*", "*Keep it up!*", "*Best class ever!*", "*The lecturer made sure that everyone knew and understood the work*" and "*The lecturer was really helpful*". While for the module evaluation, some of the responses to the open ended question for comments about the module content and delivery include "*Keep it up*", "*More tutorials should be done*", "*I found the module very useful*", "*Course well presented*", "*It was all well organised*", *The module was taught in different ways in order to improve our understanding*", "*The module helped me to integrate theory with practical knowledge*" and "*The lecturer provided everything necessary for this course and more*". The author recognises the fact that the feedback is an opportunity for self-reflection and improvement both in the way she teaches and the way in which the module was delivered despite the excellent remarks.

5. Conclusion

The analyses of the feedback of the teaching and module evaluations in a final year module in an Engineering Faculty have been presented and discussed. The author presented some of the practical and pragmatic approaches employed in delivering the module. Different methods of assessments were employed in the module to test the skills acquired by the students. All the students agreed that the assessment tasks improved their

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thinking skills while above 90% of the students either agreed or strongly agreed that the teaching methodologies employed and the course module content was appropriate. Furthermore, 98% of the students also agreed or strongly agreed that the learning activities helped to achieve the outcomes of the module. It is worth mentioning that this module had 100% throughput rate in the 2014 academic session.

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Enhancing Student-Teacher Communication in Programming Courses: a Case Study Using Weekly Surveys

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Abstract

Though various techniques to improve the student motivation and learning performance in programming courses have been developed, the aspect that is often forgotten is the communication between students and teachers. Student feedback, if properly collected and analysed, can be used to encourage self-reflection and to collect important feedback on the course methodology redesign. In this paper, we present a redesign of an introductory programming course, with focus on improving the communication between students and teachers. For this, two weekly surveys were conducted: one after the lecture, and one after a tutorial session. Each week, the feedback collected was analysed and issues addressed in forthcoming lectures and tutorials. In the paper we discuss the process of designing the weekly surveys, the methods for analysing them and the changes made in the course design based on the surveys. Also, a collective analysis of feedback collected with the weekly surveys is presented. The results show, that continuous surveying is an excellent tool for tracking errors and issues in materials, and should be utilized whenever major changes in course methodology are made.

Keywords: *Programming learning, Surveys, Course redesign, Educational technology*

1. Introduction

As seen in various studies, student performance can be significantly improved by increasing the level of active learning (see e.g. [1]). Thus, several new methodologies for teaching have been presented during the recent years. In programming, the benefits of actively engaging into process are obvious, as the best way to learn programming is to write programs. Hence, educators are eager to try out new methodologies (such as flipped classroom) in their programming courses. Still, one area which has been discussed less is the communication between students and teachers. This can be seen especially important when the course is redesigned, since adapting new methodology can potentially be difficult at first.

Facilitating communication has several potential benefits: first, the student motivation can be enhanced if the possible flaws in the course design, methods or staff can be properly communicated. Second, filling out surveys or other forms of feedback can be a powerful tool for students' self-reflection. Third, the feedback can be used to fine-tune the course methodology and materials, if analysed throughout the course. However, constant surveying must be designed carefully. Things to consider are for example the tools to collect feedback, and the rewards for answering. Rewarding is especially important if the surveys are used each week.

In this paper, we present a redesigned programming course that utilizes active learning and collaboration. The important part of the redesign was facilitating teacher-student communication by presenting two weekly surveys, one after the lecture and one after tutorial session that utilized active learning and collaboration. First, the redesign and the effects on student performance are presented. Then, the research setup is described, including the design of the surveys and the methods used for analysis. Finally, the results are presented and discussed accompanied with suggestions to fellow educators and researchers.

2. Related Work

According to various studies [2] – [5] programming is an extremely difficult skill to learn for various students. The students have problems in acquiring the required skills, and in maintaining adequate motivation throughout the course. Hence, drop-out rates are often high in introductory programming courses. Tan et al [6] state, that

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because the students do not understand the basic concepts properly, they have no interest for further exploration and self-experimentation in programming. Consequently, the problems in programming learning often become cumulative: when the basic concepts are not learned, building up further knowledge becomes impossible.

Jenkins [7] states that passive learning methods (such as lectures or reading) are not useful to convey the skills required in programming. Hence, active learning methods can be seen as a solution for redesigning programming education. Tynjälä [8] compared passive learning environment to a constructivist environment and found out that students using the latter acquired more diversified knowledge. Hadjerrouit [9] presents a constructivist approach to teaching object-oriented programming, and concludes that the learner should play an active role in constructing the object-oriented knowledge. Moreover, Wulf [10] discusses the application of constructivist approaches to teach programming in high school and undergraduate level, and concludes that utilizing such approaches enhance for example active learning and cognitive apprenticeships.

Hence, several different suggestions to enhance active learning in programming courses have been made in recent years. McDowell et al. [11] studied the effects of pair programming in introductory programming courses and found out that collaboration is an effective tool for teaching programming. Moreover, *flipped classroom* is a methodology, where lectures are delivered as videos, and the time spent in classroom is dedicated to active (and often collaborative) learning sessions. Amresh et al. [12] present a study where flipped classroom setup was utilized in introductory programming courses. While the authors state some positive effects, they also identify potential pitfalls on the setup.

Karahasanoviæ et al. [13] discuss the various issues in collecting feedback from the engineering students. The authors found the existing methods of collecting feedback insufficient, and hence developed their own feedback-collection tool which was utilized in four different experiments. They conclude, that the feedback can be used for example to check process conformance, understand problem solving process and identify problems with experiments. Sanders [14] collected students' perceptions on extreme programming and pair programming by asking them to write opinion papers, and states, that the feedback should be considered carefully before actually introducing practices into curriculum.

3. Course Redesign and Effects on Student Performance

The "Basic Course of Programming and Algorithms" is an introductory programming course at University of Turku. The course is a mandatory course for all computer science majors as well as for some other majors in the faculty. It is typically taken in the first year of studies after an introductory course in computer science. The course design traditionally consisted of fourteen two-hour lectures, demonstrations (where students presented their solutions to programming tasks assigned a week earlier) and a pen-and-paper exam at the end of the course. Hence, the methodology was quite typical for any programming course anywhere.

For the 2013 instance, the course methodology was redesigned to better facilitate active learning, teacher-student communication and proper methods for evaluation. The first step was to change half of the lectures into ViLLE (see [15]) tutorials, where students answered the exercises in collaboration with other student. Second, two weekly surveys were introduced (see the next Section for details) to receive students' perceptions on the lectures and tutorials. Finally, the exam was changed into electronic exam with automatically assessed exercises to make the evaluation process as authentic programming situation as possible.

To find out the effectiveness of the redesign, the course grades and drop-out rates were acquired from the redesigned course instance (2013) and from the instance using the old methodology (2012). The pass rate increased from 53.3 % (old methodology) to 80.8 % (new methodology). The difference was statistically significant, as confirmed by Mann-Whitney U Test ($p = 0.004$) and Kolmogorov-Smirnov test ($p = 0.001$).

A complete description of the redesign effects can be found in [16].

4. Research Setup

To facilitate the student-teacher communication, a set of surveys was prepared in ViLLE. At the beginning of the course each student answered to a simple survey about their major, previous programming experience and whether they could provide own laptop to be used in course tutorials. Additionally, after each lecture and tutorial session a small survey was conducted.

4.1. Course Structure

The course lasts for eight weeks, and contains seven learning modules (consisting of lecture and tutorial) and the final exam. The modules are described in Table 1.

Table 1. The course structure

Module	**Topic**
Week 1	Introduction to course and programming
Week 2	Strings, conditional statements and command line arguments
Week 3	Loops
Week 4	Methods
Week 5	Arrays
Week 6	Using Java's API, recursion
Week 7	Exceptions, summary

As seen in the table, structurally the course is a typical introductory programming course. Each week consists of two-hour lecture and a two-hour tutorial session, where the students solve the exercises in collaboration with another student. The tutorial sessions were organized in the lecture hall, and were supervised by various course staff members and older students (i.e. *mentors*) who assisted the students when required.

4.2. Survey Design

After each learning session (lecture or tutorial) a short survey was opened in ViLLE. The surveys were kept as brief as possible to encourage answering. Additionally, the students were awarded a few ViLLE points for answering the surveys. The survey consisted of three open questions:

a) What did you learn in this session
b) What topics remain unclear after this session
c) How would you improve the session

The questions were designed to give the course staff quick information about possible modifications needed in the course design, and to give students a change for self-reflection after each learning session.

4.3. Data Analysis

The data conducted with tutorial and lecture surveys was analysed by first counting the answers into all three questions, respectively. After that, the answers to question 3 ("How would you improve the session") were tagged into different categories. For the lecture survey, the answers were categorized under following types:

a) Suggestion for improvement: answers that clearly suggested how a lecture could be improved, including for example handing out lecture slides before the lecture or what topics should be covered in more detail.
b) No improvement necessary: answers that clearly stated that no improvements are necessary, as the lecture was good the way it was. Still, empty answers were excluded from this category.
c) Negative: answers that clearly expressed flaws in the given lecture (but did not suggest an improvement), such as "the lecture slides were too vague at some part".
d) Other: answers that were not left empty, but which could not be adequately categorized into any of the previous categories. The answers in this category mainly concerned other parts of the course (such as announcing course exam dates) or were meant as a joke (such as "It would be nice if coffee was served in the lectures").

For tutorial sessions the answers to question 3 were tagged into seven categories:

a) No improvement necessary: similar to lecture survey, the answer indicated that the tutorial was good as-is.
b) Too easy: the answer indicated that there were too few exercises in the tutorial, or the exercises were too easy.
c) Too hard: the answer indicated that there were too many exercises in the tutorial, or the exercises were too difficult.

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d) Technical issue: the answer reported an issue concerning the session arrangement, for example the problems with the network or poorly arranged seating.
e) Mentoring issue: the answer indicated that there were problems with the course staff mentoring the tutorial session, typically two few mentors or student mentors that were unprepared.
f) Content issue: the answer indicated a problem with the tutorial content design, such as two few examples or a lack of materials needed to answer the exercises properly.
g) Course design or tool issue: the answer either argued that there was something wrong with the tutorials as methodology (some students expressed dissatisfaction to the fact that the tutorials needed to be completed in collaboration and in the lecture hall), or there was a problem with ViLLE as a tutorial platform.

The categories were selected to try to catch the issues as specifically as possible. In the next section the results of analysing the survey answers are presented.

5. Results

In this section the results are presented, starting with the pre-course survey and continuing with lecture and tutorial feedback. In the final section the results are discussed and conclusions are made.

5.1. Pre-Course Survey

The pre-course survey was conducted before the first actual lecture. A total of 161 students answered to the survey. The majors of the respondents are displayed in Table 2**.**

Table 2. Major subjects of pre-course survey respondents (N=161)

Major	**N**
Computer science	67
Mathematics	27
Physics	18
Biotechnology	18
Statistics	16
Other	15
Major	N

Of all users, 125 (77.6 %) reported having an own laptop they could use in the course tutorials. Since there were two students working on each computer, this was a sufficient number.

The students were also asked to pick up their favourite learning method. The results are displayed in Table 3**.**

Table 3. Respondents' favoured learning methods

Favored learning method	**N**	**Ratio**
Demonstrations	14	8.70 %
Web based exercises	40	24.84 %
Combination of both	107	66.46 %

As seen in the table, most students preferred a combination of traditional demonstrations and web-based exercises. Notably, only a handful preferred demonstrations. Moreover, the students were asked to evaluate their previous programming experience in a scale of 1 to 5 (1 = no experience at all, 5 = very much experience). The average of all answers was 1.87 with standard deviation of 1.061. This shows, that most of the students taking the course were novices.

5.2 Lecture Feedback

The total number of answers to each question in the lecture survey for all seven lectures is visualized in Figure 1.

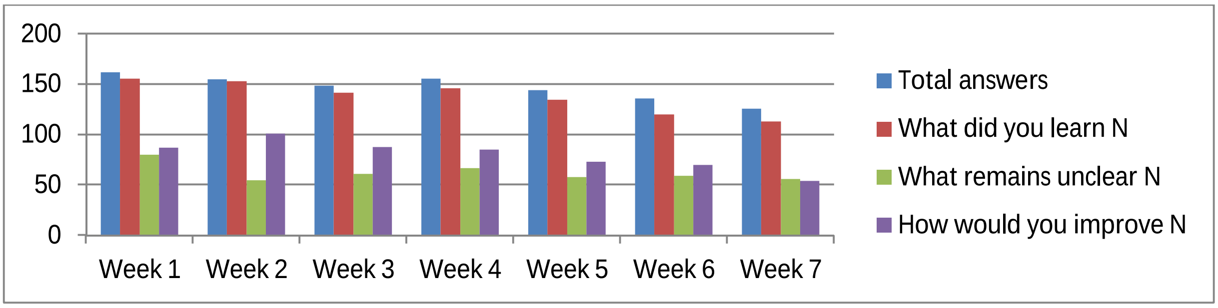

Figure 1. Total number of answers to questions in the lecture survey per week

As seen in the table, the total number of respondents decreased a little by the end of the course. For individual questions in the survey, no significant peaks are found. The answers for the question 3 ("How would you improve this lecture") were tagged by their content (see previous section for details). The results are visualized in Figure 2**.**

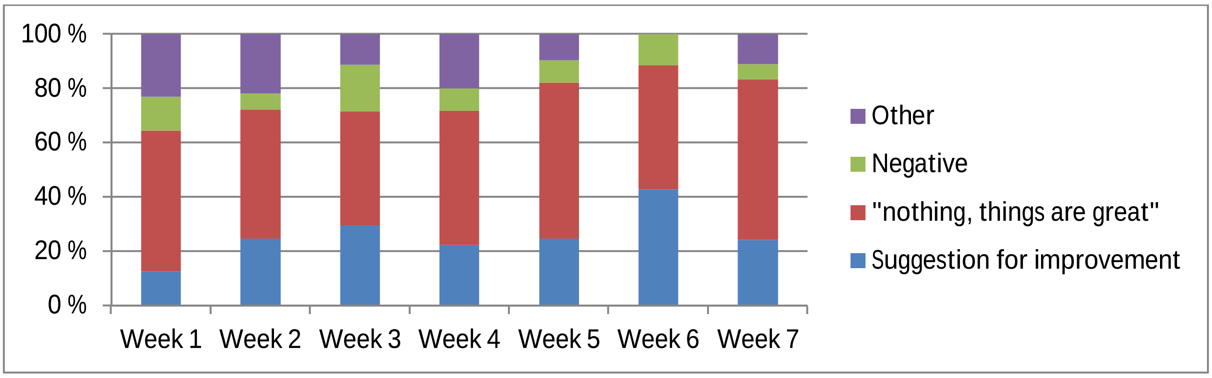

Figure 2. The answers to question "How would you improve this lecture" tagged by their content

As seen in the table, most of the respondents seemed to think that the lectures were good as-is. Moreover, the low number of negative comments seems to confirm this. Still, there were plenty of suggestions for improvement each week (and especially at third and sixth week), which is elementary to further improve the course.

5.3. Tutorial Feedback

The total number of answers to each question in the tutorial survey for each seven weeks is visualized in Figure 3.

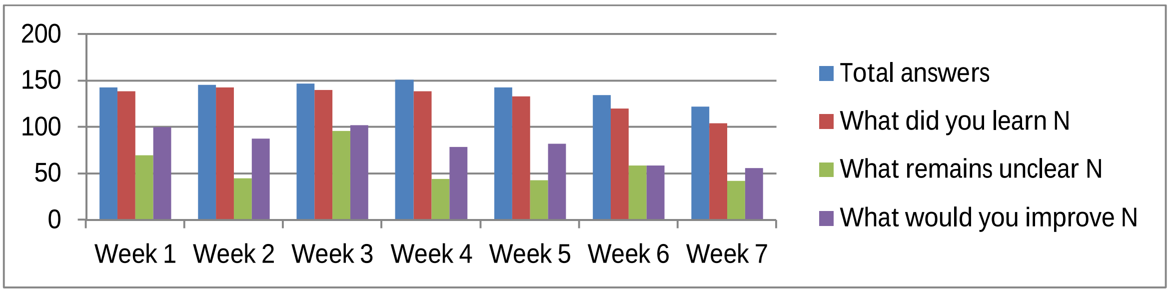

Figure 3. Total number of answers to tutorial surveys per each week

Again, the number of total responses decreased a little at the final weeks of the course. Again, the answers to the third question were tagged by their content. The answers categorized by whether they reported an issue or not, are visualized in the Figure 4.

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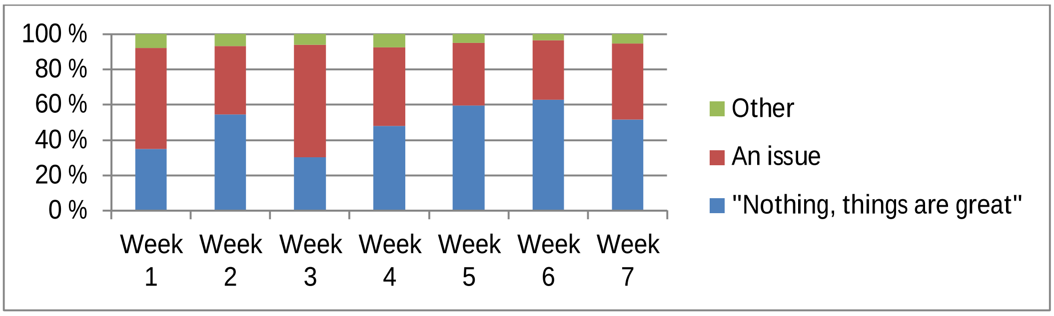

Figure 4. Issues reported in tutorial surveys

The issues reported were categorized further to find out which areas of the tutorials and tutorial sessions needed improvement. The number of students reporting the tutorial as too easy or too difficult is visualized in Figure 5**.**

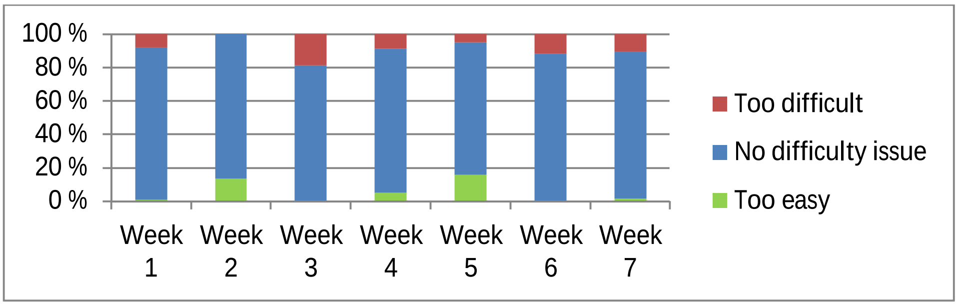

Figure 5. Tutorial difficulty issues reported each week

As seen in the table, though most of the students seemed to think that the difficulty level was adequate, some tutorials can clearly be identified as too easy (week 2) or too difficult (week 3 in particular). The other issues are visualized in Figure 6**.**

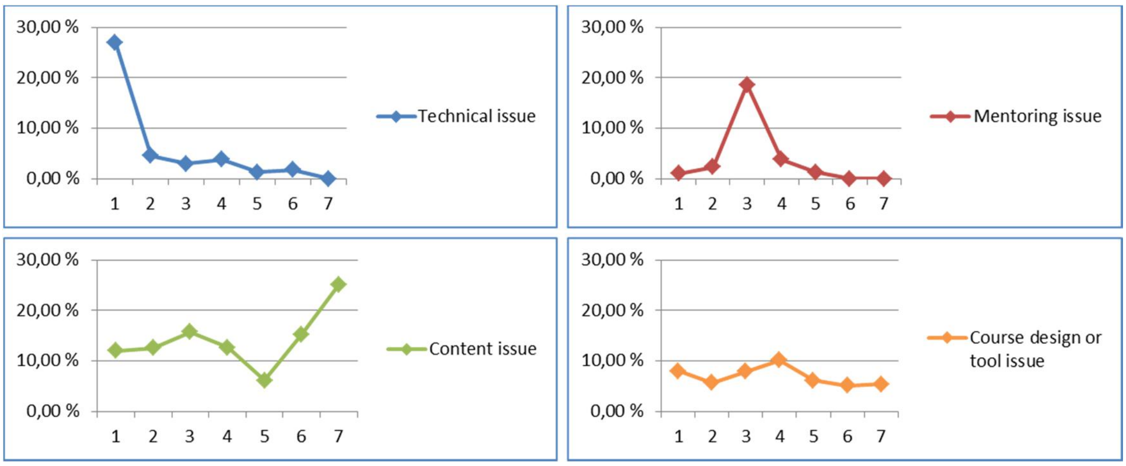

Figure 6. Other issues reported in tutorial surveys

By analysing the survey data, valid explanations for the peaks in the figures can be adequately explained. For example, the mentoring issue in the third week was based on the tutorial being seen as too difficult by various students (see Figure 5), and hence the number of mentors present was seen as too low. Moreover, the high number of content issues in the final tutorial is based on the error in the final exercise in that tutorial.

6. Conclusion

Though the number of respondents' decreased a little by the end of the course, surveys like these were still considered as an excellent tool for collecting immediate feedback after lectures and tutorials. The first question in the survey was mainly included for students' self-reflection right after the lecture. This effect was emphasized by including a few simple ViLLE exercises which were meant to be answered after the lecture. The second question ("What things remain unclear after this lecture") was briefly analysed after the lecture, and the topics mentioned were quickly addressed at the beginning of the next lecture.

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The issues raised in the lecture feedback mainly concerned technical issues such as providing lecture slides before the lecture or arguing whether there should (or should not) be a break in the middle of the two-hour lecture. There was very little negative feedback; still, some of the issues mentioned were for example the pace of the lecture (either the topics were presented too fast or too slow), and that the lecture contained too much information. Notably, various students commented, that though the topics presented might seem a little overwhelming after the lecture, things are quite clear after practicing them at the tutorials. This seems to be in favour of the redesign, where each module contained a theory session and a practice session.

Analyzing the tutorial feedback proved to be really useful for improving the course design. The difficulty level reporting shows, that tutorial at week three was seemed particularly difficult. This effect is also visible as a peak in mentoring issue reporting. Overall, the tutorial difficulty level was probably in line with the other tutorials. However, one clearly more difficult exercise was included (namely an exercise where a decimal number was to be converted into binary number without using any external libraries). It is likely, that various groups reached the exercise at the same time, and hence felt that they could not get enough help from the mentors. This was addressed in the next tutorial session by increasing the number of mentors as well as by giving more instructions for solving the exercise for the next course instance.

Technical issues in the tutorial decreased drastically after the first week. In the first tutorial, there were problems with the network functionality. Moreover, the seating order was not planned beforehand, which lead to a situation where the mentors were unable to access some groups sitting in the middle of the rows. Both of these issues were fixed after the first tutorial, which can be clearly seen as a decrease in reporting technical issues. Also, the peak in the content issues at week 7 can be explained by the fact, that there was an error in one of the exercises in the tutorial making it impossible to score the maximum. The slight peak at the week four in the course design or tool issues was caused by presentation of a new Robot exercise, which some of the students found too complex.

All in all, the number of issues reported was either constantly low or decreased by the end of the course (excluding the aforementioned content issue). Hence, the students seemed to be quite pleased with the redesigned course. Notably, the “Nothing, things are great” selection dominates the answers for most weeks both, in tutorial and lecture surveys. This is even more remarkable since the survey asked for suggestions for improvement instead of positive feedback.

Based on the feedback and the analysis, we would recommend collecting students’ perceptions throughout the course. In our opinion, there are two major advantages: first, the possibility to modify the course design during the course, and the likely positive effect on student motivation when the issues are addressed. Based on the feedback, various little modifications were made in the course: the most obvious one is fixing the technical errors and the errors in tutorial content, but other smaller issues were also addressed, such as clarifying the descriptions in the tutorial exercises.

Possible flaw of continuous feedback collection is that the students might find the constant surveys annoying or boring. This effect is slightly visible in the decreasing number of total answers received at the final weeks. In the course redesign it was decided to provide a couple of ViLLE points for answering a survey, which likely had a positive effect on the number of answers. Hence, this is also something we recommend. Other important issue to consider is addressing the issues reported in the surveys during the course. This way the students realize that their feedback has real effect, and it is likely, that they pay more attention in giving feedback.

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New trends in Chemical Engineering Education: Personal Prospective

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Abstract

Chemical engineering teaching has evolved over the last 10 years with more emphasis on product development and process intensification. Sustainability is also becoming an essential part of chemical engineering where environmental, economic and social dimensions meet. An essential part of design now incorporates safety with Life Cycle Analysis (LCA). These changes are having major impact on the chemical engineering practice especially on biotechnology and related industries. In this paper, the new trends in chemical engineering education will be highlighted along with the different accreditation criteria in Europe, UK, and the Middle East which follows an American system. The differences between these systems will be highlighted and discussed in terms of profession requirements in these regions. It is worth mentioning that these regions' education systems and accreditation policies meet at some point especially when we are talking about multinational institutions across the globe.

Keywords: *Education, assessment and sustainability*.

1. Introduction

The Chemical Engineering curriculum has been traditionally delivered in a very conservative manner up to the year 2005, despite the fact that this method has been argued to be ineffective. Many emphases were put on the unit operations approach and very little on the underlying sciences especially biological sciences and product development [1]. However the engineering discipline has been undergoing rapid change during the last 10 years. This change is driven by developments in the market world-wide, as well as societal advances and the demands from employers where a greater level of competencies from engineers is sought. A review of the content of the traditional chemical engineering curriculum is thus required along with the mode of delivery of fundamental knowledge and skills. Versatility in a number of areas and not just the core in the technical domain is required. Hence, there is great urgency to design curriculum capable of delivering well educated engineers who can contribute to all aspects of sustainable development in an increasingly competitive world [2,3].
In this paper, the curriculum changes in different continents will be investigated in terms of underlying sciences, sustainability, product and process development and project design tools. The different assessment methods of the chemical engineering programs in the US system, UK and Europe are highlighted and compared.

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2. Chemical Engineering Curriculum

Chemical Engineering around the world is going through changes in response to rapid technological advancements. The perceived change is attributed to biotechnology, information technology and nanotechnology. Many chemical engineers are finding jobs in areas other than the traditional petrochemical industry. Concern for the chemical engineering education typically revolves around core knowledge questions such as "How far is a curriculum based on classical unit operations approach will equip our engineers with necessary expertise? How about the basics? As well as "Is chemical engineering changing into computer science? Does it need more product orientation? What about bio-process engineering? [4]. The main strategy for the chemical engineering discipline is defining it within the academic knowledge that would preserve its identical identity and allow it to succeed in a rapidly changing environment. Some people think that the solution is to revise textbooks to consider applications that integrate molecular science. Others prefer the transport phenomena approach while many advocate fundamental changes concerning molecular processes, multi-scale analysis and system design and synthesis.

There have been changes in the chemical engineering curriculum across the European Union. In 2003 the European Federation of Chemical Engineering (EFCE) welcomed and supported the Bologna Process. They announced the preparation of an update of the recommendations for core chemical engineering curriculum studies taking into account recent developments in study organisation, in curricula accreditation guidelines and in science and engineering. The recommendations put much emphasis on the learning outcomes. The core curriculum covers about two thirds of the curriculum and leaves space for modifications and innovations.

In France a large number of engineers successfully moved to administrative positions where their work has served national interest. They focus on problem solving as an applied science combined with engineering lateral thinking. In Germany, there has been emphasis on the development of quality techniques in terms of process and product development coupled with cost reduction techniques.

Sustainable development has been introduced into the new curriculum in chemical engineering at the individual level and often in elective courses. In fact there is a high demand for the introduction of this concept into the curriculum even at an early stage. The work by Blottnitz *et al* [5] presented a review of a reformed undergraduate curriculum with central focus on sustainable development. It was even introduced in the first year of the curriculum as a core course. This study even shows that complexity can be added in the first year of the curriculum through theory, project, practice and assessment. The inclusion of the project in the first year has added additional teaching and learning challenges. It has also enhanced engagement, stimulation with regard to the inclusion of sustainable development issues.

In the US, More underlying sciences have been introduced into the curriculum especially biological sciences. This was mainly driven by the biotechnology industry in the fields of food, pharmaceutical, renewable energy (biofuels) and waste management technologies. Product development from molecules to products has also been introduced into the chemical engineering curriculum.

In the UK, the curriculum changes have been very conservative in terms of introducing more of the biological sciences, except in some universities and despite the efforts of the Institution of the Chemical Engineers in this regard. There has been more emphasis on process intensification and product development. In some European countries, chemical engineering curriculum is a mixed bag of chemical sciences and engineering practice. Sometimes, it is not very clear whether the degree is in chemical engineering or in industrial chemistry from which chemical engineering evolved over the years. This is a reflection of the chemical industry in Europe which is different to that in the US and the UK. Over the last 10 years, there have been more scientists (especially chemists) involved in the development of the curriculum which became research driven.

While the sustainable development has been introduced to the curriculum in the Western World at a large scale, in other countries such as in the Middle East and China, the chemical engineering curriculum has been the same for many years. This is due to the oil and gas industry which is dominating in this region. The environmental impact of chemical processes is having little consideration in the curriculum despite the accreditation efforts, mainly, by the American Institute of Chemical Engineers (AICHE). As a result, the introduction of biological sciences has become a major component. However, neither sustainability nor product development has been largely introduced into the curriculum except in the final year design project.

3. Industrial Feedback and Support

Teaching faculty in many universities in the US, UK and other regions are increasingly becoming research active and this is impacting on the curriculum development and tracks in chemical engineering. The industrial experience is not passed on to many universities for the reason and the requirement for faculty members to have a rich research record in preference to industrial experience. This is despite that many industrial members in institutions worldwide are chemical engineers. In the UK the Royal Society is trying to fill the gap between industry and academia, by offering industrial placements for new faculty members in chemical engineering schools. This came under major criticism since most universities are not willing to jeopardise their academic ranking, which is mostly dependent on research output.

4. Accreditation and Assessment

4.1. Introduction

Engineering professional bodies around the world have devised a road map by directly linking the impact on economic growth through various means such as technology, learning, access and quality. In order to maintain quality human resource in the professional engineering practice, accreditation and assessment of engineering degrees must become a key focus. This would foster engineering education for socioeconomic development at all levels. This is vital to identify and realize achievements and goals through the engineering profession and to attain student learning outcomes in accordance with both institutional and professional criteria.
In this section the assessment by professional international bodies such as the AICHE, IChemE and EFCE will be highlighted in terms of achieving learning outcomes of the chemical engineering degree programs. A comparison between the three will be made based on personal experience in the IChemE accreditation in the UK and ABET accreditation in the US system.

4.2. ABET Accreditation

Accreditation is proof that a collegiate program has met certain standards necessary to produce graduates who are ready to enter their professions. Students who graduate from accredited programs have access to enhanced opportunities in employment; licensure, registration and certification; graduate education and global mobility. ABET accreditation has impact on students, programs and institutions, public and professionals in business and government. Accreditation is an assurance that the professionals who serve us have a solid educational foundation and are capable of leading the way in innovation, emerging technologies, and in anticipating the welfare and safety needs of the public.

- Before an institution submits a formal Request for Evaluation for a program, the program must have in place processes for internal assessment. These processes may take several years to develop. During this preparation phase, a program must:
- Implement the assessment process for program educational objectives and student outcomes.
- Demonstrate a continuous improvement loop.
- Collect student work examples.
- Review the most up to date Accreditation Criteria, Accreditation Policy and Procedure Manual, and Self-Study Questionnaire(s) which are updated every year.

ABET accreditation is based on eight general criteria – (i) Students, (ii) Program Educational Objectives (PEOs), (iii) Student Outcomes (SOs), (iv) Continuous Improvement, (v) Curriculum, (vi) Faculty, (vii) Facilities and (viii) Institutional Support. There may be additional program specific criteria. [ABET, 2015].

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In the UK chemical engineering continues to evolve rapidly as a profession. Nowhere is the need to take account of change more important than in the education and academic formation of engineers. Accreditation makes sure that new graduates have the necessary minimum skills to perform in an ever-wider variety of roles and industries. Moreover, they must not only be equipped to contribute quickly during their early careers, but also have a quality academic grounding in chemical engineering principles 'to last a lifetime'. IChemE responds to this challenge with its accreditation activity, through which educators benefit from our knowledge of best global practice in chemical engineering education. IChemE concentrates upon assessment of 'learning outcomes' (i.e. what is learnt by students) rather than traditional methods of specified degree program content (i.e. what is been taught to students). The accreditation is done at two levels; the Master level (MEng) and Bachelor level (BEng) with emphasis on a number of learning outcomes [6]. The IChemE looks at the learning outcomes [7] with the number of the European Credit Transfer System (ECTS) as shown in Table 1,

Table 1. IChemE Accreditation: minimum credit allocation guidance
Credit basis = European Credit Transfer System (ECTS)

Item	Master Level	Bachelor Level
Underpinning mathematics and science	20	20
Core chemical engineering	85	85
Engineering practice	10	10
Embedded learning (sustainability, SHE)	Sufficient	Sufficient
Embedded learning (general transferable skills)	Sufficient	Sufficient
Advanced chemical engineering (depth)	55 with a minimum of 10 in each category	-
Advanced chemical engineering (breadth)		-
Advanced chemical engineering practice		
Advanced design practice	5	-

As Europe is implementing the Bologna two cycle degree systems, the European Federation of Chemica Engineering (EFCE) has put in place recommendations for accreditation. The recommendations cover the learning outcomes which include general and transferable skills and knowledge. It will also cover achieving the learning outcomes in terms of the core curriculum; teaching and learning; industrial experience; review of the educational process and student assessment. This is done through two cycles that are known as the first and second assessment cycles [8].

4.3. Personal Prospective

In this section two case studies of accreditation will be presented. The accreditation of chemical engineering in Sultan Qaboos University (ABET accreditation) and the Queen's University of Belfast (IChemE) will be discussed in terms of the learning outcomes mapping and other aspects of the accreditation process.

The Program Educational Objectives (PEO's) of the chemical engineering are to prepare graduates so that few years after graduation they should be able:

- **PEO-1:** To become skilled Chemical and Process engineers who can serve as professional role models for the next generation;
- **PEO-2:** To take part in the development of the country's Chemical and related industries and are able to work abroad;
- **PEO-3:** To develop themselves professionally or follow graduate studies;
- **PEO-4:** To apply principles of mathematics, chemistry, and chemical engineering to the design and operation of safe, economically feasible, and environmentally responsible chemical and petroleum processing systems.

The learning outcomes in Sultan Qaboos University relation to the different objectives is shown in Table 2.

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Table 2 Mapping of the program objectives to the learning outcomes in Sultan Qaboos University

Program educational Objectives → **Student Outcomes**	**PEO1**	**PEO2**	**PEO3**	**PEO4**
A) *An ability to apply knowledge of mathematics, science, and engineering*	√			√
B) *an ability to design and conduct experiments, as well as to analyze and interpret data*	√			
C) *an ability to design a system, component or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability. .*	√		√	√
D) *an ability to be a team player working in multi-disciplinary fields.*	√	√	√	
E) *an ability to identify, formulate, and solve engineering problems*	√		√	√
F) *an understanding of professional and ethical responsibility*	√			√
G) *an ability to communicate effectively*	√		√	
H) *the broad education necessary to understand the impact of engineering solutions in a global and societal context*		√		√
I) *a recognition of the need for, and an ability to engage in life-long learning*		√	√	
J) *a knowledge of relevant contemporary issues*		√		√
K) *an ability to use the techniques, skills, and modern engineering tools necessary for Engineering practice.*		√	√	√

The different outcomes (A to K) are mapped in the different courses as shown in Table 3 below.

Levels of Emphasis:

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↑ **High**	→ **Medium**	↓ **Low**	blank = little or none.

Table 3. Learning outcomes mapping in the different courses

semester	Code	Course Name	A	B	C	D	E	F	G	H	I	J	K
		ABET A-K	A	B	C	D	E	F	G	H	I	J	K
		PIs											
4	CHPE3102	Engineering Thermodynamics	↑	↓			→				↓		↓
4	CHPE3112	Principles of Chemical Processes	↑				↑		↓	↓			→
5	CHPE2211	Organic Chemistry	↑	↑					→		↓		↓
5	CHPE3302	Fluid Flow	↑		↓		↑	↓	↓	↓	↓		→
6	CHPE3101	Materials Engineering	↑	→		↓		↓			↓	↓	↓
6	CHPE3211	Applied Physical Chemistry	↑	→	↓		↓		↓		↓		↓
6	CHPE3402	Heat Transfer	↑	↓			→				↓		↓
6	PNGE3202	Numerical Methods	↑	→		↓	→		↓		↓		→
6	ECCE 3015	Fundamentals											
7	CHPE3103	Professional Practice				↑		↑	→	→	↓	→	
7	CHPE4112	Thermodynamics	↑	→	→		→		↓		↓		→
7	CHPE4212	Unit Operations I	↑	→	↑	↓	→	↓	↓		↓		→
7	CHPE4312	Chemical Engineering Lab I	→	↑		↑		→	↑		↓		→
7	PNGE4101	Statistics for Engineers	↑	↑		↓	↓				↓		↑
8	CHPE4114	Computer Aided Design	↓		→	→	↑		→				↑
8	CHPE4412	Process Heat Transfer	→		↑	→	↑	↓	↓	↓	↓		→
8	CHPE4512	Chemical Reaction Engineering	→	→	↑	↓	↑	↓	↓	↓	↓	↓	→
8	CHPE4612	Unit Operations II	→	→	↑	↓	→	↓	↓		↓		→
8	PNGE5103	Engineering Economy	↑	→		→	↓	↓	↓	↑	→	→	→
9	CHPE4712	Chemical Engineering Lab II	→	↑		↑		→	↑		↓		→
9	CHPE5112	Chemical Process Control	↑	→	↑	↓	↑	↓	↓		↓		↑
9	CHPE5312	Project I	→	↑	↓	↑	↓	→	↑	→	→	↑	↑
9	CHPE5412	Plant and Process Design	↑	→	↑	→	↑	→	↓	↑	→	→	→
9	PNGE5203	Management for PCE		↓		→		↑	→	→	↑	↑	→
10	CHPE3212	Chemical Process Industries	↓			↑		→	→	↑	→		↓
10	CHPE5212	Chemical Engineering Lab III	→	↑		↑		→	↑		↓		→
10	CHPE5512	Project II	↑	→	↑	↑	↑	→	↑	→	→	↑	↑
	PNGE5102	Health, Safety and Environment	↓	↓		↑		↑	↑	↓	→	↑	↓
	CHPE5612	Chemical Process Safety	↓	↓		↑	→	↑	→	→	→	→	→
	CHPE5712	Process Integ, Syn and Sim	↑	→	↑	↓	↑	→	↓	→	↓	→	↑
	CHPE5812	Hetero Catal and Rct Des	↑	→	↑	↓	↑	↑	↓	→	↓	→	→
	CHPE4102	Polymers	↑	↓	↓	↓	↑	→	↓	→	→	→	↓
	CHPE4202	Corrosion	↑	→	→	↓	↑	↑	↓	↑	→	→	↓
	CHPE4302	Desalination	↑	↓	→	↓	↑	→	↓	→	→	→	↓
	CHPE4402	Natural Gas Processing	↑	↓	→	↓	↑	→	↓	↓	→	→	↓
	CHPE4812	Special Topics I											
	CHPE4912	Special Topic II											
	CHPE5207	Petroleum Refining Processes	↑	↓	→	↓	↑	→	↓	↓	↓	→	↓

The assessment process has two parts. These are the direct assessment of the different courses including the final year design project and the indirect assessment. The indirect assessments are carried out via student-faculty liaison committee, student exit interview, and student exit surveys, activities of students' society, and industrial advisory board meetings. The learning outcomes assessment data are collected from the different courses in the curriculum. Direct and indirect assessment results are checked for deficiencies which will be fed back for corrective measures to improve the performance. This is known as continuous assessment which is a major component of the assessment process.

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Queen's University Belfast went through accreditation in 2011. The learning outcomes are mapped to the different courses in the curriculum from basic introductory courses through intermediate core chemical engineering courses including design in the second year. The breadth and depth of knowledge is also mapped to the second and third year courses and the design in the final year project. The ethics and safety outcomes are evaluated in the final year design project and the loss and prevention course. The skills required are assessed in the final year project, marketing project and the professional studies course.

Having been involved in accreditation by both ABET and IChemE, a comparison between the two systems can be made. It is obvious that all accreditation systems are to make sure that there are processes in place to maintain the quality of chemical engineering education and that the graduates possess the necessary skills for long life learning. The accreditation process feeds back into the curriculum where changes are adopted to ensure that the curriculum and the education can cope with the technological, economic and social constraints. The IChemE accreditation looks at the depth and breadth of knowledge and focuses on the safety, health and the environment (SHE) while ABET focuses on the Ethics, biology component and the different outcomes especially the transferable skills. The role of the external examiner in the UK accreditation is a major component of the process and it can influence the outcome greatly. The role of the external examiner in the US is not very well defined and in many institutions is non-existent. The outcomes in the ABET accreditation are quantified numerically and always reported as minimum acceptable range even when there is a rubric in place that describes the outcome. The accreditation panel in the UK is composed of industrialists and academics while the ABET is mainly academic.

5. **Conclusion**

ABET accreditation is always evolving to take into account new developments in education and assessment. Training courses are offered at different times of the year while the IChemE offers very little training and it is always conducted via the rules and guidelines published on the IChemE website. ABET accreditation is becoming like a business tool especially for these conducting the accreditation process. Despite all this, accreditation is in our opinion is an essential tool to maintain the quality of education in chemical engineering.

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Students' Perception of Learning Facilitation during an Interdisciplinary Engineering Design Course – A Case Study

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Abstract

Important engineering competencies can be developed within a Problem-Based Learning (PBL) environment. However, learning facilitation plays a major role in guiding students' learning towards the anticipated learning outcomes. The purpose of this case study is to analyze students' perception of learning facilitation during an interdisciplinary engineering design course delivered using a PBL approach. Based on criteria from a PBL inventory [1], students' feedback on their PBL facilitator was collected. The results show that students' project work led to overall positive learning outcomes. Also, students were found to show a strong preference to work as a multidisciplinary team as opposed to an interdisciplinary team. From the case considered here it can be inferred that learning facilitators may have the potential to improve formative assessments (i.e. feedback) during students' project based learning. Furthermore, the connection of students' project work with the anticipated learning outcomes may need to be reinforced. This is to ensure that students realize they are carrying out projects so as to learn pre-defined knowledge and skills.

Keywords: *Problem-Based Learning, learning facilitation, students' perception, engineering design.*

1. Background

Important engineering competencies can be developed within a Problem-Based Learning (PBL) environment. The PBL approach originated at McMaster University [2] and the characteristics of PBL have been summarized as follows [3]:

- Students must have responsibility for their own learning;
- Problem simulations must be ill-structured and allow for free inquiry;
- Learning should be integrated from a wide range of disciplines;
- Collaboration is essential;
- What students learn during their self-directed learning must be applied back to the problem with reanalysis and resolution;
- A closing analysis of what has been learned from working with the problem, and, a discussion of what concepts and principles have been learned is essential;
- Self and peer assessment should be carried out at the completion of each problem and at the end of every curricular unit;
- The activities carried out must be those valued in the real world;
- Student examinations must measure student progress towards the goals of problem-based learning; and,
- Problem-based learning must be the pedagogical base in the curriculum and not part of a didactic curriculum.

Different variations, models, and perspectives on PBL have emerged [4, 5, 6] and led to approaches such as "Problem-Oriented and Project-Based Learning" [7] and "Problem-Based Project-Organized Learning" [8]. The common focus of the PBL variations and models is learning around problem scenarios rather than discrete subjects [9]. The problem scenario could be a badly structured situation, which is tackled as a project (Project-Based Learning), or could be a case (Case-Based Learning), as it is common in medical education, psychology, social science or science education [10, 11]. Most PBL models are classified as "hybrid models" since they include aspects of traditional learning approaches such as lectures [12, 13]. Research has shown the potential benefit of a PBL supplementing lecture [14]. PBL stimulates critical thinking, self-learning skills, lifelong learning, self-achievement, self-regulation, self-efficacy, communication skills, interpersonal skills and students' motivation [15]. Most of these competencies are among the competencies required from graduates by professional bodies such as Engineers Australia [16].

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The importance of learning facilitation (versus teaching) within a PBL environment has been already stressed by Boud and Feletti [12] who emphasized the importance of facilitators' own self-awareness and psychological sensitivity [17]. Learning facilitation was also one of the key dimensions of PBL as identified by Lowernthal [18], and the importance of learning facilitation during a PBL Engineering Skills course has been shown recently [19]. Based on twenty-one PBL environment characteristics taken from Senocak's PBL Environment Inventory [1] and an Exploratory Factorial Analysis (EFA), [19] showed that all characteristics belonged to one of the following groups of characteristics:

- Learning facilitator support;
- Student responsibility; and,
- Project quality.

Based on this study [19], learning facilitation seems to be as important as the students' responsibility for their learning, and, the quality of their learning project. However, a Confirmatory Factorial Analysis (CFA), carried out as part of the same study, showed that the strongest influence on students' ability to succeed in the course came from the perception of the students' own responsibility, followed by their perception of the project quality. Interestingly, virtually no influence on students' ability to succeed came from the perception of the facilitator support. This confirmed that projects need to be carefully chosen in order to match students' ability to succeed, and, supporting lectures used to explain design tasks in more detail may support the development of students' responsibility for their learning. Although facilitator support was not perceived as having a direct influence on the students' perception of their ability to succeed, the study showed that the importance of learning facilitation lies in facilitators' feedback, motivation, stimulation, encouragement and guidance during the PBL process and problem solving work (e.g. project work).

2. Purpose and Course Description

The purpose of this study is to identify students' perception of their facilitator support during the delivery of the course "Engineering Design and Management - Implementation", with the aim to contribute to a continuing improvement process of learning facilitation related to PBL engineering design courses.
The course is based on two pre-requisite PBL courses, "Engineering Skills" and "Engineering Design and Management – Planning", and the course learning outcomes are shown in Table 1.

Table 1. Learning Outcomes.

1	Apply the techniques of project management to design and implementation of engineering projects
2	Develop a personal framework for engineering design and project management processes and for the roles of stakeholders in these processes, based on evidence of reflection on design and project management
3	Design or select as appropriate, components and elements for the project, relevant to disciplines
4	Develop a detailed project design consistent with relevant Standards and engineering practice from a conceptual design and client approved project specifications
5	Model and evaluate the detailed design
6	Demonstrate and justify the incorporation of a systems approach to design activities based on a sustainability framework, which includes social, environmental, economic, business, usability and health & safety benefits and risks
7	Identify, justify and apply the technical knowledge and skills required to successfully complete an engineering project
8	Produce professional and technically competent project management and design documentation
9	Produce professional and technically competent project management and design documentation
10	Provide evidence of a professional capacity to communicate, work and learn; individually and in peer learning teams

At the end of the course each of the fifty students was required to submit the following portfolio items for assessment:

- Reflective Journal showing thoughts on their learning and learning process;
- Workbook showing work related to the project;
- Drawing Folder of technical drawings related to the project;
- Peer- and Self-evaluation (strengths and weaknesses in essay style to reflect the ability of professional judgments; peer-evaluations did not impact lecturer evaluations);

- Individual Grade nomination; and,
- Reflective paper on an interview with a practicing engineering about the project.

Course learning outcomes, assessment criteria of the course learning outcomes and details regarding the portfolio items were explained to the students during week one of the semester, and it was emphasized that all portfolios will be assessed individually (i.e. no "team marks"). The learning facilitator facilitated students' learning throughout the course through formative assessment and feedback in a manner consistent with the PBL environment [1] and assessed students' portfolios at the end of the course. Finally, each student had to undergo an individual *viva voce* to explain their work and learning.

The intentionally loose, problem description, included the following information:

> *An owner (represented by your learning facilitator) wants to build a typical villa in a local residential area. An architect finished already the architectural drawings (uploaded to the LMS) and the owner is satisfied with the architectural design. However, he wants to convert it into a "Green Building". The owner requires from an engineering design firm (design team) to find a cost-effective solution which reduces the energy consumption by 50%. Specifically, he is asking the engineering firm to re-design two components of the villa:*
> *1. Re-design the external wall structure and find a solution which is as sustainable as possible.*
> *2. Re-design the AC system and find a solution which is as sustainable as possible.*
> *The owner requests the calculations and drawings of the solution to be ready in week 5. The design team must design the solutions according to relevant standards and regulations and based on industry standard practices. Required material needs to be locally available.*
> *Furthermore, he requests from the design team to hand over the design documents (drawings and related documentation) in week 5 to a third-party contractor (production team), in order to have the suggested solutions tested.*
> *Specifically, the owner is requesting two tests in week 13, which prove that the solution "really works". In week 13, he wants to see one test related to the external walls, and another test related to the AC system. It's up to the production team how they want to carry out the test and how they want to prove the effectiveness. Professional interaction with the design team will be necessary.*
> *The production team needs to manage the purchase process (from requesting quotes, evaluating offers, negotiations with suppliers, writing a purchase order, quality control of delivered material, to paying) and afterwards submitting a filled-in reimbursement request form. In order to qualify for reimbursement, your purchase order needs to be approved by your learning facilitator.*
> *Evaluation of the design solutions will be based on meeting the requirement of 50% reduced energy consumption and, secondly, on the net cost increase of the solution (i.e. cost increase of external walls and AC system) compared with conventional solutions.*

In contrast to proceeding PBL courses, where student teams were assigned by the course leader, it was decided to allow students at this stage to manage the team building process themselves, meeting the requirements that teams had to include at least two students from each discipline (civil and mechanical engineering), and, teams had to consist of four or five students. During the first five weeks of the semester, student teams were requested to work as interdisciplinary design teams and to present their design solutions in week five to a different team assigned by the learning facilitator. This team was requested to work as the production team throughout the remainder of the semester. In this way, each team worked as a design team and, on a different project, as a production team. This scenario triggered the need for interaction between design and production teams as well as potential for the need to resolve conflicts. Communication with the "owner" (represented by the learning facilitator) was kept to a minimum since the owner was just interested in an economically and environmentally sustainable solution which would meet the requirement of 50% reduced energy consumption.

Each week of the semester included a one hour project related presentation by the learning facilitator, and four hours per week were scheduled for team work, during which the learning facilitator was also available for feedback and guidance. The course outline (syllabus) included a learning schedule (Table 2) which showed the weekly presentation topics in addition to some events and activities which students were encouraged to consider as the basis for development of their personal schedules and team schedules.

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Table 2. Learning Schedule.

Week	Presentations by learning facilitator	Student activities
1	Introduction to course, project and effective group norms	Team formation & building; Team ethics statement; Team schedules
2	Design Process	Individual: Carry out interview with practitioner (Reflective Paper), Design Team: Research and analyse typical solutions
3	Heat Transfer	Design Team: Research applicable material and analyse properties, Develop and discuss design ideas
4	Air Conditioning	Design Team: Select design, Prepare workshop drawings
5	Risk Identification	Design Team: Present design solution to production team / submit documents, Individual: Reflective Paper due
6	Procurement Process	Production Team: Verification of documents, purchase material
7	Safety Management, Project Communication	Production Team: workshop, Design Team: monitoring
8	Time Monitoring	Production Team: workshop, Design Team: monitoring
9	Budget Control	Production Team: workshop, Design Team: monitoring
10	Quality Control	Production Team: workshop, Design Team: monitoring
11	Guest Presentation “Green Buildings”	Production Team: workshop, Design Team: monitoring
12	Testing Procedures and communication of testing results	Production Team: workshop, Design Team: monitoring
13	Reflection	Production Team: Testing of design solution / products, Design Team: Finalizing Design Report, Individual: Portfolio submission
14	*Viva Voce*	*Viva Voce* Timetable TBA

The presentations by the learning facilitator in week 2 and 3 were very important for the students’ learning process and had a direct influence on the development of design ideas. In week 2, the presentation included aspects such as energy transfer, conduction, convection, radiation, simultaneous heat transfer mechanisms and thermal resistance. In week 3, topics covered were dry and atmospheric air, specific and relative humidity, dew point temperature and modelling the Air-Conditioning process.

3. Method

Table 3 shows the questions which were used to measure students’ perception of learning facilitation. These questions were selected from the PBL environment inventory [1] since they matched similar questions, albeit composed differently in order to evaluate traditional courses (i.e. non PBL courses), of the college’s SETL (Student Evaluation of Teaching and Learning) questionnaire. Students were asked to answer the shown questions on a 5 point response scale (from 1 - strongly disagree to 5 - strongly agree) and the survey was conducted after students’ portfolio submissions, but prior to students’ *viva voce* (i.e. before students were informed about their final grades).

Table 3. Student Survey Questions.

1	The Learning Facilitator directed us with some stimulating questions
2	The Learning Facilitator gave us a clue instead of the correct answer, when we had a question
3	The Learning Facilitator considered my performance during the problem solving process
4	The Learning Facilitator asked us how we arrived at a solution
5	The Learning Facilitator provided us with positive and negative feedback on our project work
6	The Learning Facilitator encouraged us to use various information sources
7	The Learning Facilitator encouraged us to express our ideas clearly
8	The problems were of the kind for which one can produce different solutions
9	I had to collaborate with the other members of my group
10	The problems we studied were related to the learning outcomes
11	I felt the need to use various information sources

In addition to these questions, students’ were encouraged to add any other remarks related to the course on the bottom of the questionnaire.

4. Observations

Before the results of the questionnaire survey are shown and discussed, observations regarding the students' project work are described.

Even though no specific or detailed instructions were given, all teams were able to develop design solutions and built appropriate "testing devices". They utilized information from the presentations by the learning facilitator, literature, local building code, standards and meetings with practitioners. For example, students of one "testing device" chose plywood panels and glass wool insulation (Figure 1). Students of another "testing device" preferred gas-aerated concrete blocks (Figure 2).

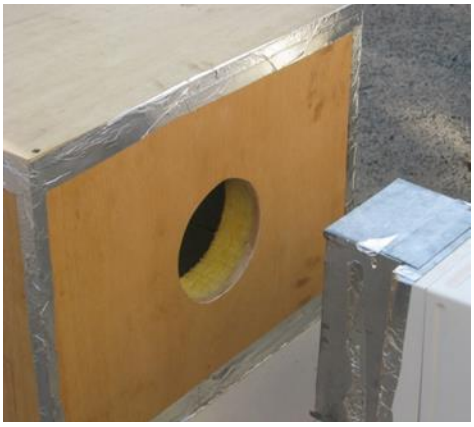

Figure 1. "Testing device" based on plywood and glass wool insulation.

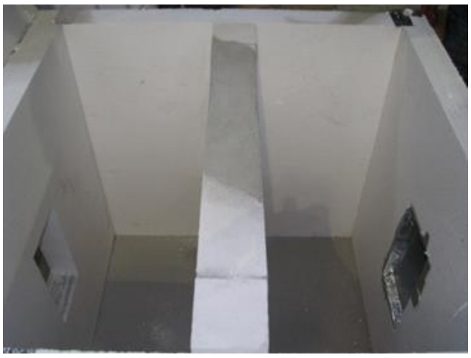

Figure 2. "Testing device" based on aerated concrete blocks.

As may be seen from Figure 1, students had to think about appropriate connections with an Air-Conditioning unit, required insulation and possibilities to measure temperature and time. Testing of the design solutions (i.e. measuring room and surface temperatures of walls and ducts, with infrared and electronic thermometers) enhanced students' critical reflection on their design.

Most students felt there were advantages of interdisciplinary work, where discipline specific knowledge was required. The same was observed regarding complementing different skill sets. However, the learning facilitator strongly encouraged the learning of new knowledge and skills by team members from the discipline that was not their own.

Although students enjoyed group work, a strong trend from interdisciplinary to multidisciplinary work (i.e. work carried out by different disciplines without much interaction) was observed. Two main reasons for this were identified: First, students realized it was saving time if students from the two disciplines focused on more familiar knowledge and skills; and, secondly, students' identification with "their discipline" was quite strong and resulted in two sub-teams (i.e. a civil engineering sub team and a mechanical engineering sub team). Two "reminders" helped to counteract this trend, and, increased students' interest and participation in work carried out by team members of the other discipline:

a) "You may also be asked during your individual *viva voce* about work which was carried out by other team members"; and,
b) "*Teaching others* is one of the assessment criteria which needs to be met in order to be assessed *excellent* in Learning Outcome No. 10".

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The first "reminder" especially led to an increased participation in the work carried out by students of the other discipline. Although it is not focus of this study, it should be mentioned that students had to solve more team conflicts than during their team work of the two pre-requisite PBL courses (Engineering Skills, Engineering Design and Management Planning), when the Learning Facilitator had assigned students to teams.

5. Discussion of Survey Results

Table 4 shows the results of the questionnaire survey. The maximum possible mean value was five and even the lowest agreement (i.e. No. 8) which was 4.3 is still considered high. The five statements with which there was least agreement are now discussed.

Students agreed least with statement No. 8 (The problems were of the kind for which one can produce different solutions). Students did not perceive the large variety of potential solutions and may need more encouragement from the learning facilitator to "think outside the box".

The second least agreement was with statement No. 2 (The Learning Facilitator gave us a clue instead of the correct answer). Since the Learning Facilitator was consistent in counteracting questions with clues and hints, the result cannot mean that students perceived the Learning Facilitator as giving correct answers instead of mere clues. However, the result may point towards the impression that not enough clues were given.

Students were more united (i.e. lower SD) in the trend towards disagreement with statement No. 3 (The Learning Facilitator considered my performance during the problem solving), which may point towards potential for improving learning facilitation. The Learning Facilitator needs to increase formative assessment during students' project work. Although the Learning Facilitator gave individual feedback to students when they presented their design ideas in week 5, this was obviously insufficient since students may have presented parts of the design solution which was actually developed by another member of the design team, or it may have been copied from other students.

Responses to statement No. 1 (The Learning Facilitator directed us with some stimulating questions) show less disagreement than responses to the previous statements. However, similar to statement No. 2, the learning facilitator does not see potential for improving stimulating questions. The reason for the students' perception might have been the students' misinterpretation of the phrase "directed us" as "helped us". Anecdotal evidence shows that the students studied here interpret "help" as "receiving correct solutions". However, the learning facilitator intentionally did not give correct solutions, since developing solutions was the task of the students.

A similar level of disagreement to statement No. 1 was with statement No. 10 (The problems we studied were related to the learning outcomes). Although the learning outcomes were explained in week 1 of the course, this may have been insufficient and the learning outcomes need to be connected to the project work more frequently. Again, the standard deviation for this statement was the highest and interpretation requires adequate caution. However, the result may confirm an earlier finding which showed that PBL students need to be reminded throughout the course that the course is not primarily about carrying out projects, but about learning based on carrying out projects [20].

Table 4. Results of Questionnaire Survey [1 - strongly disagree to 5 - strongly agree].

No.	Question	Mean	SD
1	The Learning Facilitator directed us with some stimulating questions	4.5	0.70
2	The Learning Facilitator gave us a clue instead of correct answers	4.4	0.78
3	The Learning Facilitator considered my performance during the problem solving	4.4	0.60
4	The Learning Facilitator asked us how we arrived at a solution	4.7	0.46
5	The Learning Facilitator provided us with positive and negative feedback	4.6	0.78
6	The Learning Facilitator encouraged us to use various information sources	4.6	0.60
7	The Learning Facilitator encouraged us to express our ideas clearly	4.6	0.48
8	The problems were of the kind for which one can produce different solutions	4.3	0.69
9	I had to collaborate with the other members of my group	4.6	0.72
10	The problems we studied were related to the learning outcomes	4.5	0.78
11	I had to use various information sources	4.8	0.45

6. Conclusion

The purpose of this study was to identify students' perception of their facilitator support during the delivery of the course "Engineering Design and Management - Implementation", with the aim to contribute to a continual improvement process of learning facilitation related to PBL engineering design courses. The interpretation of students' responses shows that the learning facilitator needs to increase formative assessments (i.e. feedback) during students' problem solving process. Furthermore, the connection of students' project work with the anticipated learning outcomes may need to be referred to more frequently in order to ensure that students realize they are carrying out projects in order to learn defined aspects.

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E-portfolio for Global Human Resource Development Program

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Abstract

Japanese government selected 37 universities as the Top Global Universities among 758 universities in Japan in 2014 in order to enhance their international competitiveness. The government financially supports the selected universities. Shibaura Institute of Technology has been elected as a top global university. For the global human resource development program, we designed an e-portfolio system with three portfolio categories. The first category is the learning portfolio, which consists of rubrics as evaluation standards for measuring the degree of achievement of learning outcomes. The learning portfolio also provides a weekly-report submission site for students exchange and overseas internship programs. The second category is the carrier portfolio, which includes the Progress Report On Generic skill test (PROG test) as a means of generic skills assessment and reflection for students. Third category is the language portfolio. For the language portfolio we adopted the Common European Framework of Reference Languages: Learning, Teaching, Assessment (CEFR) and extended it to technical communication capability assessment. The e-portfolio system has been utilized to assess global project based learning courses, student exchange and overseas internship programs, and has proven to be effective in motivating students and improving the quality assurance of these educational programs.

Keywords: *portfolio, global, PBL, rubric, internship, cross-cultural.*

1. Introduction

In 2014, Japanese government selected 37 universities as the Top Global Universities among 758 universities in Japan in order to enhance their international competitiveness. The government financially supports the globalization of these selected universities, including seven technical universities. Shibaura Institute of Technology (SIT) is the only private technical university among those which has been elected as a top global university. In addition, SIT established South East Asian Technical University Consortium (SEATUC) with leading technical universities in South East Asia in May 2006, and has been strengthening its collaboration with overseas universities. Along with these globalization steps, SIT has been implementing its Global Human Resource Development Program to educate students in global environment. In this paper, we introduce an e-portfolio system designed and implemented at SIT to advance its global education.

2. Global Human Resource Development Program

We designed the Global Human Resource Development Program in order to strengthen students' abilities in relation to four aspects of global skills: global leadership skills, communication skills including technical communication in a foreign language, problem-solving skills with ethics and inter-cultural understanding with the recognition of their identity.

(1) Global leadership skills:
The ability to cultivate international cooperation with a long-term vision, a sense of commitment, and a can-do attitude in a positive sprit of collaboration.
(2) Communication skills:
The ability to understand and to have others understand products and services in the field of engineering by using language skills.
(3) Problem-solving skills:
The ability to identify and solve problems by using problem-solving skills based on the social impact of technological and economic activities.
(4) Intercultural understanding skills:

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The ability to appreciate cultural diversities as well as a strong sense of the identity of one's own country and the ability to convey these attitudes though one's action.

In order to develop the abilities mentioned above, we initiated Global Project Based Learning Courses by enhancing international university collaborations and our Engineering English Overseas Training Programs. Also, we increased student exchange and overseas internship programs (Figure 1). We determined clear educational objectives, measured the outcomes, and executed a Plan-Do-Check-Act (PDCA) cycle of quality assurance of the education.

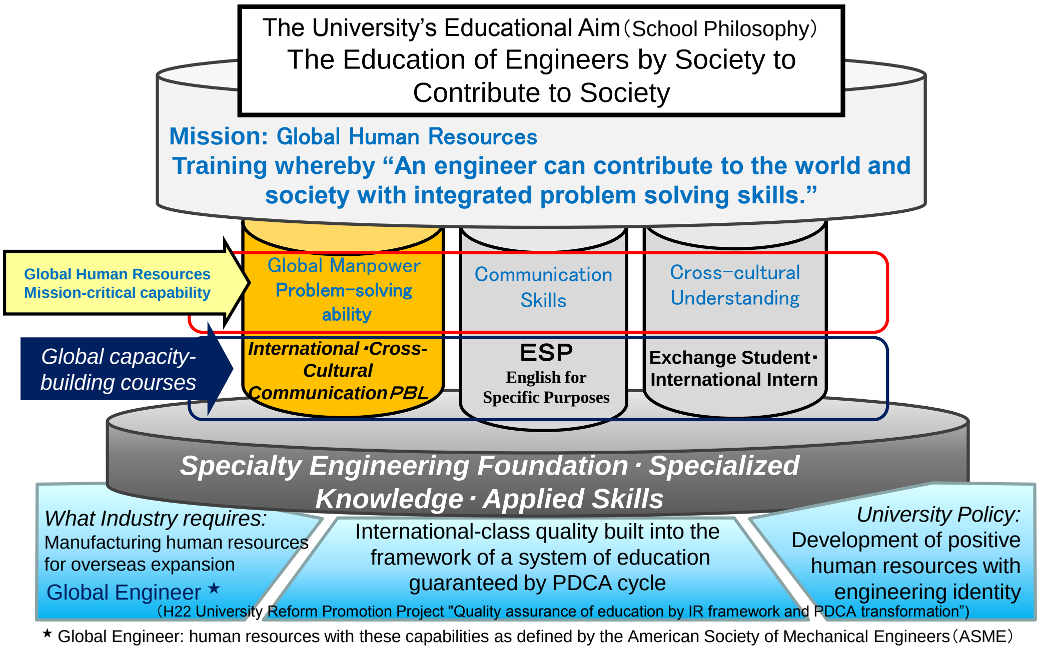


Figure 1. The University's Educational Aims and Global Human Development Program

3. E-portfolio: Objective and Requirement

3.1. Definition and Objective of the e-portfolio system

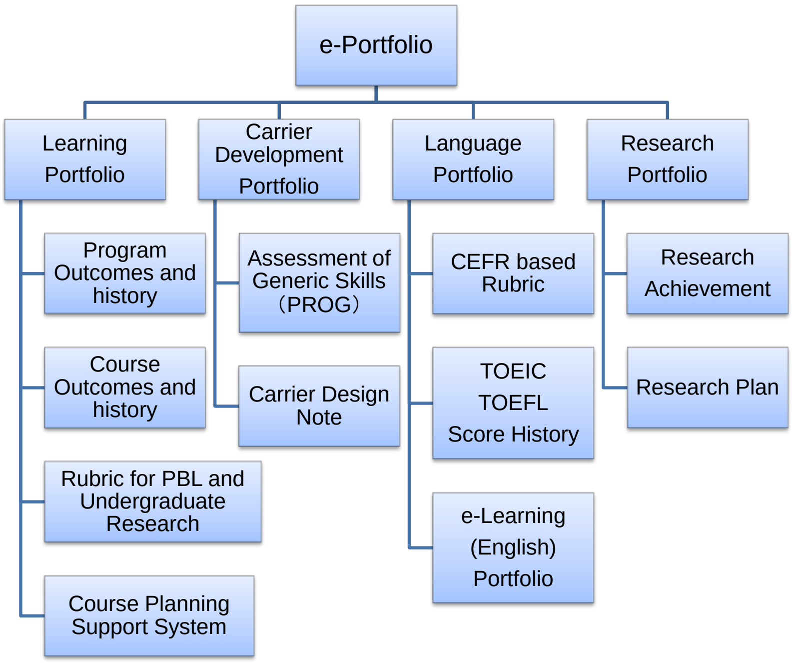
An e-portfolio system was developed as part of an educational program of the global human resource development. The portfolio system is an electric accumulation of achievements and career developments of students. One of the objectives to implement the e-portfolio system is to facilitate the reflection of students for active learning, and exhibiting and sharing the products of students among students, faculty members, and the society [1]-[5].

3.2. Requirements for the e-portfolio system

We analysed requirements for the e-portfolio system by taking in account both the goals of global human resource development programs and demands form stakeholders. We defined the stakeholders of the human resource development program as students, faculty members, staff members, and partner universities and companies involved in our student exchange and overseas internships programs. Project Based Learning Courses [6], Engineering English overseas trainings, student exchanges, and oversea internship have been improved to develop the four aspects of global skills. For each education program, clear learning and educational objectives have been determined and the learning outcomes have been quantitatively measured to execute its PDCA (Plan, Do, Check, and Act) cycle for the quality assurance of education. The e-portfolio system was designed to meet the following requirements. It has to motivate students and improve the quality assurance of the educational programs. Its interface has to be easy for students to use and to enable them to access the system at anytime and anywhere by using PCs, tablet PCs and smart phones. Also, it can be used by students to use for their carrier selections.

4. E-portfolio: Design

We designed three categories of e-portfolios for the program (Figure 2). The first one is a learning portfolio, which consists of rubrics as evaluation standards for measuring the degree of achievement of learning outcomes. The learning portfolio also provides a weekly-reports submission site for students participating in overseas exchange programs and overseas internship programs. The second category is a carrier portfolio, which has the Progress Report On Generic skills test (PROG test) as a means of generic skills assessment and reflection for students. The third category is a language portfolio. For the language portfolio, we adopted the Common European Framework of Reference Languages: Learning, Teaching, Assessment (CEFR) and extended it to technical communication capability assessment. The e-portfolio has been utilized to assess global project based learning programs, student exchange programs, and overseas internship programs, and proved its effectiveness in motivating students and improving the quality assurance of these educational programs.



CEFR: Common European Framework of Reference for Languages
PROG: Progress Report On Generic Skills

Figure 2. E-portfolio for Global Human Resource Development Program

4.1. Learning portfolio

The learning portfolio was designed to assess the learning outcomes of SIT's educational programs and to provide reflection for students. For this portfolio, rubrics were defined for engineering education to show learning objectives clearly to students and to assess the outcomes of educational programs [7]. A rubric is a scoring guide that clearly differentiates levels of student performance. Rubrics provide a clear description of proficiency levels of students' work and serve as a guide for helping students achieve and exceed a performance standard. The rubrics supply not only the basis for self-assessment by students but also evaluation by faculty members.

We implemented the global PBL course as a joint program of Shibaura Institute of Technology and King Mongkut's University of Technology, Thonburi in Thailand [8]. In the global PBL course, students form project teams, and each team decides on a project theme through team discussion on keywords suggested by faculty members—such as ecology, energy, eco-tourism, mobility, welfare and medical systems, and disaster prevention. The project teams are composed of multidisciplinary, undergraduate-graduate mixed, and Japanese, Thai and Indonesian international students. This culturally diverse team structure can realize a simulating global environment, which resembles the situation that students can encounter at workplace in their future (Figure 3).

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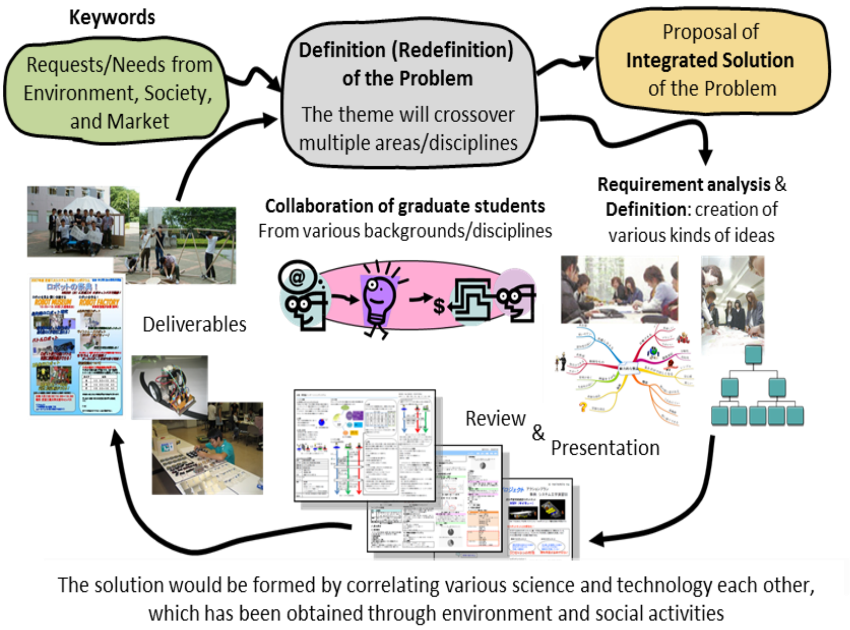

Figure 3. Process for Global Project Based Learning Course

gPBL Outcomes Assessment Sheet YYYYMMDD:
(for student)

Bachelor/Master Grade: Number: Name:

Personal Outcomes Self and Peer Assessment (High::5,4,3,2,1:Low)

	Learning Outcomes	Competency	Self Assessment	Peer #1 Name	Peer #2 Name	Peer #3 Name	Peer #4 Name	Peer #5 Name	Peer #6 Name	Average of Peer
			-							-
Personal Outcomes	Work in multi-culture and interdisciplinary team	Communicate and teamwork in multi-culture and interdisciplinary team								
	Engineering Design	Design system, service and process which satisfies needs and constrains								
	"System Thinking" - Solve interdisciplinary problem by understanding engineering process	1.Understand engineering process and apply it to solve interdisciplinary problem. 2. Recognize and analyze problem, and design and evaluate solution.								
	"Engineering Methodology" - Apply engineering methodologies to solve interdisciplinary problem.	1.Understand engineering methodologies and apply them to model, and determine system.								

Team Outcomes Self Assesment (High::5,4,3,2,1:Low)

	Project Outcomes		Self Assessment
Team Outcomes	Originality	Propose original system and service	
	Usefulness	Propose useful system and service	
	Accuracy	Based on scientific analysis and engineering design	
	Feasibility	Technically, socially and economically feasible	
	Goal	Set appropriate goal	
	Achievement	Achieve goal	
	Written and Oral Presentation	Written presentation	
		Oral presentation	

Figure 4. Assessment sheet for Global Project Based Learning Course

Criteria of evaluation for the deliverable of Global Project Based Learning Course on the final presentation are indicated as Team Outcomes in Assessment sheet for Global Project Learning Courses (Figure 4). The Deliverables were evaluated with a five-point scale from 1 to 5, based on the following evaluation standards:

(1) Creativity: Did the group obtain a creative result?

(2) Applicability: Did the group obtain a result that is to the point of the theme, which is applicable to general or global problems?

(3) Completion: Did the group obtain a result with a higher degree of completion through conducting an analysis, planning, and evaluation?

(4) Feasibility: Did the group set a goal with an adequate level of feasibility?

(5) Achievement to the Goal: Did the group achieve the goal that was set at the beginning?

Evaluation on the learning outcomes as follows was made after the global PBL course was completed. Figure 5 shows an input view for the electronic Learning portfolio based on Rubrics.

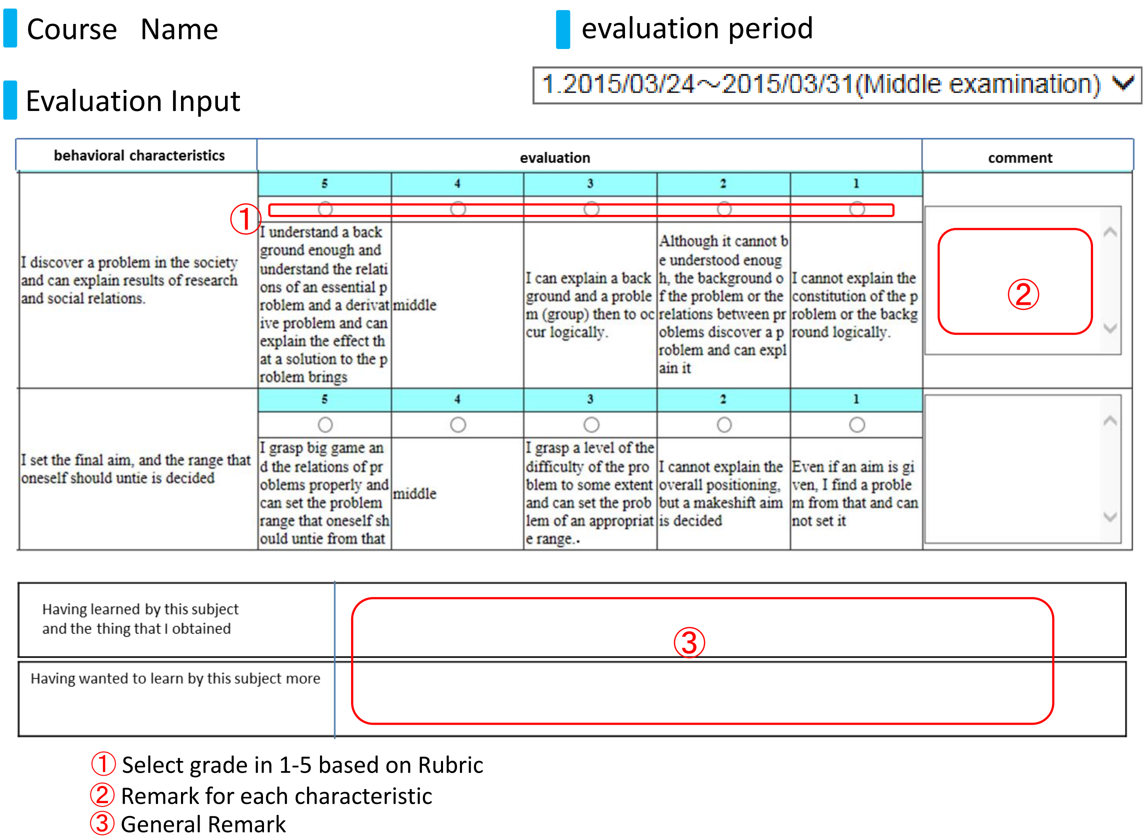

Figure 5. Learning portfolio based on Rubrics

4.2. Carrier e-portfolio

A test to assess generic skills, Progress Report On Generic skills test (PROG test) [9] has been carried out to validate this educational program in terms of the development of students' competency, since competency is necessary for global human resources. A PROG test measures the "competency" as generic skills obtained from students' experience and the "literacy" as abilities based on the students' knowledge. Students take a PROG test when they are in the first and third year of university, the first year of their Master's program, and just after they complete Global PBL courses. The strucure of a PROG test is shown in Figure 6.

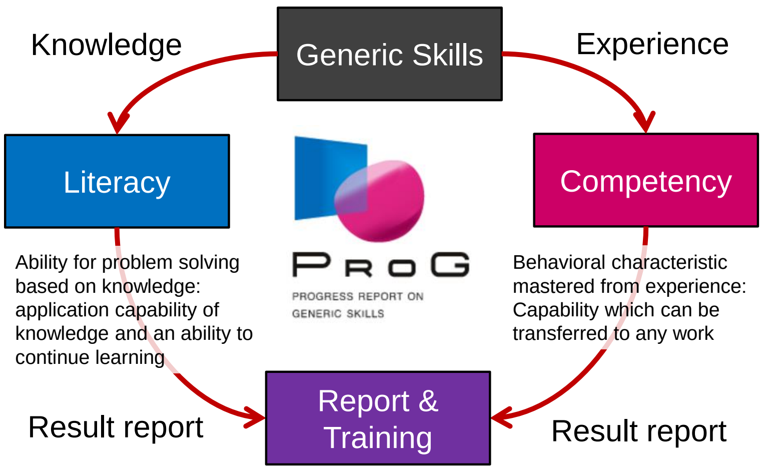

Figure 6. PROG test: Progress report on generic skills

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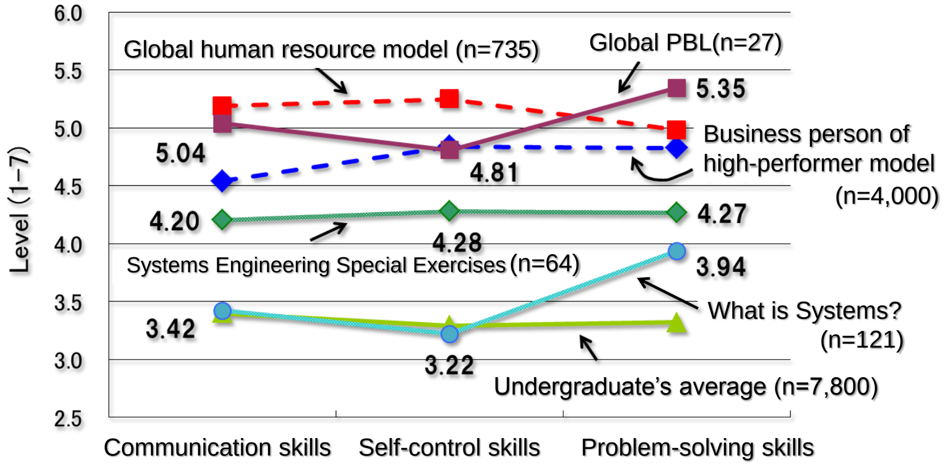

Figure 7. Competency Generic Skill: Progress Report On Generic skills (PROG)

We compared the results of PROG tests taken by students in the first and third year of university, the first year of their Master's program, and by students who completed Global PBL courses, with the results of the test taken by high-performance (domestic) busssiness professionals and high-performance global bussiness professionals. Figure 7 shows the levels of competency with three types of skill sets: commucation skills, self-control skills, and problem-solving skills. The results showed that students who had experience with Global PBL reached a high level of problem solving skills and communication skills.

4.3. Language e-portfolio

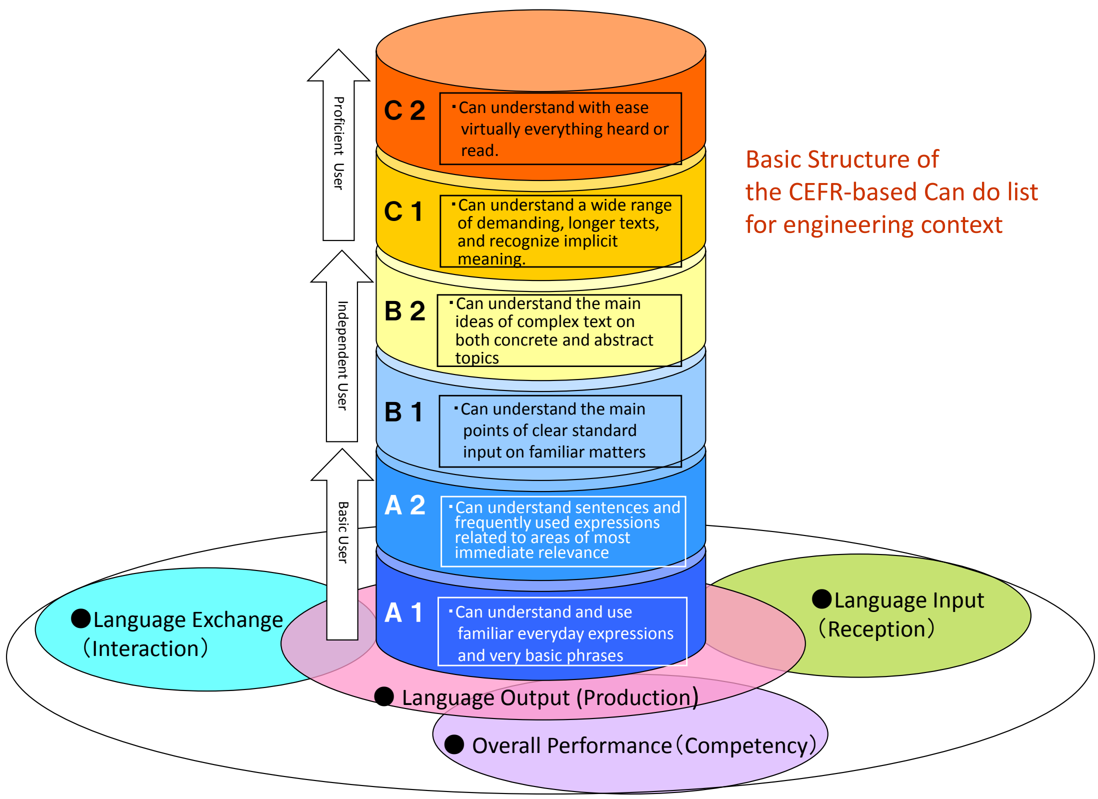

Figure 8. Common European Framework of Reference Languages: Learning, Teaching, Assessment (CEFR)

We aim to develop human resources who can work in a global environment and communicate sucessfully in English in techincal context. A means to measure the achievement of foreign language communication skills in engineering context is required to assess the learning outcomes which can not be measured in a general English proficiecy test such as The Test of English for International Communication (TOEIC). We adopted CEFR (The Common European Framework of Reference for Languages: Learning, Teaching, Assessment) criteria (Figure

8) and created a Can-do list, which is an extension of CEFR criteria for engineering context. The Can-do list is a self-assessment criteria of foreign language communication skills. It is an indicator of achievement of language communication skills in engineering contents. The Common European Framework of Reference for Languages: Learning, Teaching, Assessment (CEFR) has been proposed by The Council of Europe for a common achievement indicators for languages. CEFR index is not intended to be limited to the English but to each language. CEFR has three levels of the ABC (Basic User = Level A, Independent User = Level B, Proficient User = Level C). Each level is divided to two sub level and total steps are composed of A1, A2, B1, B2, C1, C2. CEFR Can-do list in engineering content is divided into the four language activities (Production, Resception, Interaction and Competency). Studets are required to fill out the CEFR Can-do list every year and during Global PBL courses. The results of the CEFR Can-do list have been anlyzed in a collelation with TOEIC test scores.

4.4. System Configuration for e-portfolio and Learning Management

Figure 9 shows the configuration of the Portfolio/LMS system, which has a web server, a web application server, and a DB server that is interfaced to a Bussiness DB server. The e-portfolios can be access by using a PC and a smartphone via the Internet.

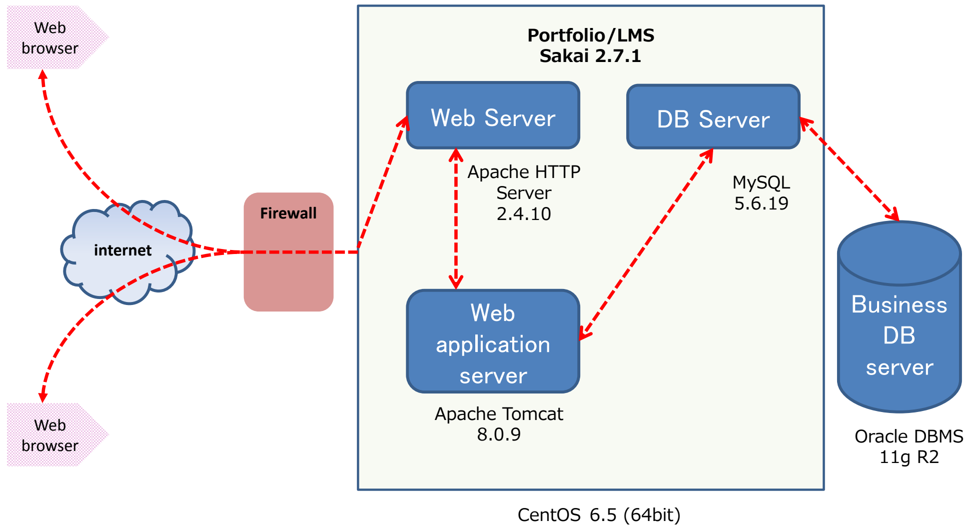

Figure 9. Portfolio/LMS system configuration diagram

5. Conclusion

For global human resource development programs at SIT, we designed and implemented an e-portfolio system with three categories of portfolios: learning portfolio, carrier portfolio, and language portfolio. The e-portfolio system has been utilized to assess project based learning courses, student exchange programs, and overseas internship programs. The outcomes of the e-portfolios proved that the design of the portfolio system was effective in motivating students and it had improved the quality assurance of the educational programs. The analysis of the e-portfolios shows that it is useful for international education programs that involve students with different cultural and language backgrounds. For Global PBL courses, we prepared the PROG tests and the rubrics in different languages, such as Japanese, English and Thai language. The CEFR Can-do list was also prepared in Japanese and Thai language. The analysis also indicates that international collaboration among universities in different countries can be more useful when the quality of international education programs jointly provided by the universities is assured by utilizing the e-portfolio system and data exchange through the system.

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How Soft are "Soft Skills" in Engineering Educations?

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Abstract

Engineering education communities have long recognized that graduates not only need to poses technical knowledge in their chosen disciplines, but also need to be better educated in areas of communication skills, teamwork and leadership. Several studies mention these so-called "soft" skills as increasingly important for future engineers. Such skills include communication, cooperation, creativity, leadership and organization. For many years, the engineering educations at Aalborg University have been working with the Problem Based and Project Organized Learning pedagogical approach. An important part of the first year engineering curriculum is to learn how to make a project and how to work in groups. Part of the study is about getting these "softer" qualifications. Students are given the course "Communication, Learning and Project management (CLP)" and are at the same time working in groups so they can transfer theory into practice. In addition to their project, students have to make a "Process Analysis", which is an evaluation of their experience of the soft skills or process competences. Results show that "Soft Skills" are hard to learn.

Keywords: *Process competences, Problem Based Learning, Project work, Group wor*

1.Introduction

Engineering education communities have long recognized that graduates not only need to posess technical knowledge in their chosen disciplines, but also need to be better educated in areas of communication skills, teamwork and leadership [1]. Several studies mention the so-called "soft" skills as increasingly important for future engineers, where such skills include communication, cooperation, creativity, leadership and organization [2]. Another study showed that "soft" skills topped the list of what employers would be looking for when hiring an engineering candidate beside the technical skills, and that employers view communication skills (98%), and teamwork skills (92%) as being important or very important when hiring for entry-level positions [3]. "Soft Skills", or process competencies as we will call them, include conscious awareness of own learning, creativity, collaboration, communication, independent work, behavioral changes, self-management and self-evaluation, etc. The concept of competencies can be seen as an individual's potential capabilities [4], and represents the potential for personal development [5]. Process competencies cover more or less the same as transferable skills, generic skills; higher order skills, metacognitive skills etc.

In this paper we focus on the development of process competencies for students at the Faculty of Engineering and Science at Aalborg University. An essential part of the working life of an engineer takes place in project-

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organized environments. At Aalborg University, we want to educate students so they become qualified to enter directly into a project organized working environment after their studies. We do this by applying the problem-based and project organized learning processes into various parts of their education. The students must be able to plan, manage and be in charge of projects. They must be able to organize themselves internally in a project group, and have competencies within co-operation and communication. In short, they have to develop the necessary process competencies to be able to work as team members or team managers in a project organized working environment [6].

When teaching process competences, one of the main challenges is how to transfer the idea of such tools and methods as one that is a useful asset for the students, and in turn, how to evaluate this in a meaningful way for both students and teachers.

Since Aalborg University was established in 1974, students of engineering have had a part of their education organized with regard to achieving these ambitions [7]. The teaching of process competencies is thought through a course in Cooperation, Learning and Project Management (CLP) and implemented by the project supervisors in the first year program at Faculty of Engineering and Science, Aalborg University [8]. The course is taught by a group of teachers, who have their background in both engineering and educational research.

This paper describes the current content of the 1st year CLP course and the didactic principles on which it is based. We analyze the students' Process Analyses reports with the conclusion that achieving soft skills or process competences is very important but also difficult, but it also show how the making of the Process Analysis allows students to review their project work, and give some well-argued suggestions for improvements.

A recent questionnaire from 2nd year students shows that they after completing the CLP course, many would want their knowledge about process competences refreshed or improved. This suggests that process competences (or "soft skills") are needed and valued, but take time and continuous practice to acquire, are generally hard to use in practice, and need to be maintained for many students to be at their disposal when necessary.

2. Theoretical Background for Teaching and Learning Process Competencies

The objectives of the course are that the students obtain theoretical and practical skills within the CLP framework [7]. Teaching in this field is based on experience-based pedagogy and the purpose is to train the students to work in an experimental and reflective way, described by Schön as the reflective practice [9]. Process competencies are special, because they are learned and developed through practice – but at the same time imply an awareness, which is developed through reflection and experimentation.

The didactic approach is based on facilitating actions, experiments and reflection. The theoretical understanding is based on an experience-based pedagogy, as the process competencies are in fact an integrated part of the individual's world of experiences [6].

We have developed a learning theory model (as illustrated in Figure 1). The model is an illustration of our theoretical understanding of how students acquire process competencies as well as a didactic tool [6].

2.1. A Learning Strategy Based on Experimentation and Reflection

Our basic approach to facilitation of experimentation and reflection is based on Schön [9], Kolb [10] and Cowan [11]. The three authors have different understandings of how experiments and reflections can be used as learning strategies.

Schön's basic concepts are "reflection-in-action" and "reflection-on-action". "Reflection-in-action" is a process where reflection and experimentation take place at the same time – in any case it is difficult to separate the two processes. "Reflection-on-action" is reflection at a distance and contains an element of evaluation of former actions. Cowan add reflection before action, which is both about how to use previous experience in general and how to use experience from previous learning situations. Kolb [10] does not deal with reflection as a method - but it is an important element in a learning process consisting of experience, reflection, conceptualization and experimentation. It is important to emphasize that reflection and experimentation is separated - and that it is an analytical, objective and observing reflection, which involves a distance to what is going to be reflected on [11].

When developing our model, we used Schön and Kolb as a starting point in order to find methods, which are operational in the development of process competencies. We began by developing various types of reflection. Our research data lead us to use three different types of reflection [6]:

Common Sense Reflection means to be conscious of the experience. This is an everyday consciousness which Schön calls espoused theories [9]. The knowledge, which is gained from the experience, is not questioned. The *Comparative Reflection* is learning through comparing different experiences. Finally, *Vertical Reflection* is based on induction and deduction – to be able to pass from single experiences to more abstract categories and vice versa.

We later became aware of the importance of working with the experiment as a learning strategy. There are several reasons for developing experiments as a learning strategy:

- By experimenting it is obvious to define objective, methods, outcomes etc. It gives the possibility of gaining awareness of action.
- It is a method for creating innovative experiences – to provide the opportunity for setting the stage for creativity, new thinking and innovation.
- It fits very well with the learning style among engineering students, who are much more active than passive. Most of the engineering students have an accommodating or converging learning style.
- Experimentation is a traditional way of defining learning and innovation among engineers.

It is important to stress how the types of experimentation we are referring to are very different from the traditional scientific approach to experiments, such as e.g. controlled experiments. The experiments we are referring to are linked to the students practice. Here, it is very difficult (for anybody) to limit areas for control – which means that it is not merely a question of achieving knowledge, but practically trying different strategies and activities as a solution to the problem that has to be solved [5]. These experiments are often generated by the teachers.

2.2. A Didactic Model Based on Experimentation and Reflection

Fundamentally, we do not understand Kolb's learning circle as a circle, where learning only takes place if the learner reflects, forms his/her own conceptual understanding, tests hypothesis, acquires new experiences as the basis of reflection etc. (see figure 1). If we analyze our own students, they do not always go "full circle",

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i.e. the whole way round the learning circle. On the contrary, at the beginning of the CLP-course students tend to go directly from the reflective observation to new experiments without any conceptualization. If the students are going to conceptualize, this has to be facilitated through questions and learning concepts, theories, models and methods connected to the field in question.

Reflection-in-action is not only deliberate and structured reflections, but also an awareness which is based on susceptibility, empathy and intuition [6]. Reflection-in-action contains two essentially different forms of awareness: Conscious reflection and intuitive awareness. Sometimes the most important aspects in group-based project work are those created by the intuitive awareness, which includes motivation, commitment and drive for the individual student either through studies or work.

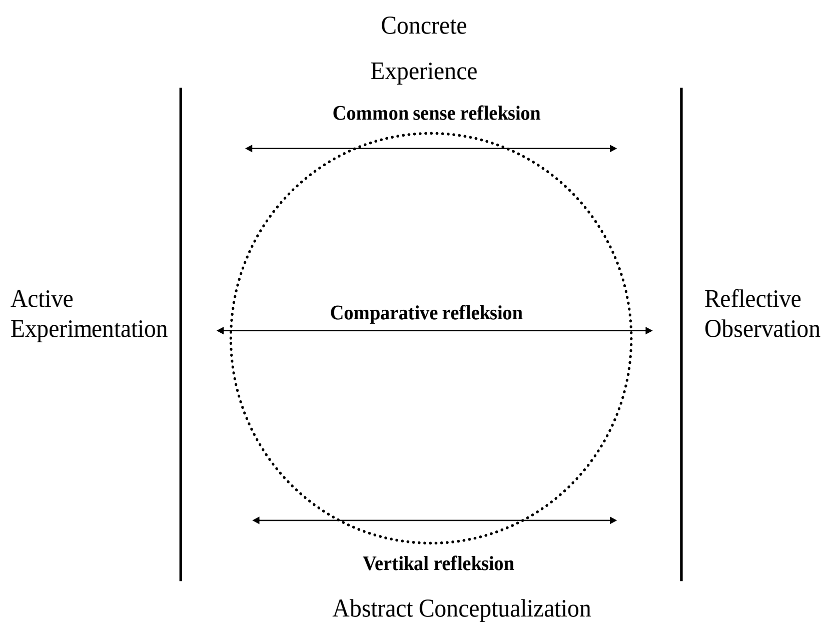

Figure 1. A didactic model developed to understand the theoretical approach to the CLP course. It contains different types of experimentation and reflection, which is related to a Kolb inspired learning circle [5,6].

Conscious reflection and intuitive awareness are important aspects of all work - and at the same time very difficult to relate to - and to teach. In the CLP course we deal with this aspect in connection with a discussion of which conditions that create inner motivation, commitment, drive and peace of mind is in focus. The problem concerning this type of teaching is that all you can do is to attract the students' attention to the fact that here is a large and important potential in connection with their development of process competencies.

3. The Co-operation, Learning and Project Management Course

The CLP Course is a 2,5 ECTS course taught at the 1st semester and extra consultation is offered for all groups on the 2nd semester. The following is a short description of how the above didactic method has been translated into the CLP course [7]. The structure of the course is based on four subjects:

1. Learning and problem-based project work
2. Project management and project planning
3. Organization, co-operation, communication and conflict handling
4. Reflection and development of the project group (Process analysis)

The courses are traditional classes, workshops and seminars. Students are often given small experiments to try out in their group. The course has two written assignments and is finished with a written exam.

3.1. Learning and Problem-based Project Work

The concept of Problem-based project work refers to a method, where the students are working with problems in their projects. At Aalborg University the students have to find, formulate and solve / discuss a problem, which can be guiding for their project. Behind this approach is an implicit wish to educate engineers, who are able to find and solve problems through critical analyses – and an understanding that the process of solving problems consists of interplay between formulating the problem and focusing on the solution. Therefore, we have chosen to call the total process "problem managing". The students learn that parts of a solution to a problem is found while you are working to reach a better understanding of the different components of the problem, and that the understanding of the problem often will change while you are working with it. At the same time, they should understand that one way of regarding a problem is trying to solve it. This illustrates the interplay between formulating and solving the problem. In relation to the didactic model this is exactly what the reflective practitioner is doing, when he/she is by turns reframing the problem through experiments and communication in the group and by reflecting on the outcome of the experiments.

During their project work the students are in groups of 6 - 7. Each semester is divided in 15 ECTS for courses and 15 ECTS for the project. Each group has 1 or 2 teachers (supervisors) connected, and they know about the CLP courses and are able to support and facilitate the students within this area.

The theory and methods from the course are implemented simultaneously into the students' semester projects. Some of the most important, but difficult subjects are as follows:

3.2. Project Management

Students must obtain knowledge and skills in project planning and management techniques [7]. Project management is defined as answering the question: *What do we want to do and how do we carry out our plans?* It is a question of pinpointing the aim of the project and the means to achieve the aim. We do not use much literature, which advises finished solutions to how projects are planned and managed. The argument in favor of this is that a specific project-planning tool can be seen as an integrated part of the project group's way of co-operating, principles of organization, and communication. Teaching is based on the principle that project plans are seen as a visualization of the project group's common understanding of the aims and means of the project. Therefore, they have to be adapted to the organizational structure, which is used by the project group, and which fits into the actual composition of personalities and experiences.(Examples from previous groups are given).

3.3. Organization, co-operation, communication and conflict handling

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During the CLP course, the student groups are inspired to experiment with their internal organization and forms of co-operation for their semester project. Students get several methods and tools dealing with communication, but teaching mainly consists in challenging the group's initial organization through a number of facilitating questions. For example we ask them about their form of management, how they share the work, roles and functions as chairman, secretary etc. Furthermore, the students are presented to a number of inspiring examples of how former project groups organized themselves.

One of the themes in co-operation is conflict handling. The starting point is a positive approach to conflict handling, where conflicts are seen as a potential for development. They indicate the presence of a dynamic in the organization where they arise. In the course we stress that conflicts should be prevented through co-operation relations considering positive conflict handling. Conflicts may originate in different attitudes to ambitions, engagement, management system, allocation of roles, understanding of problems etc. Conflicts are often the visible incentive to change the organization of the group.

3.4. Reflection and development of the project group – The Process Analysis

The experiences obtained by the students from the training during the course and their experiences from the project work are presented in an additional report called a Process Analysis [7]. The Process Analysis works as a tool for development of competencies, documentation of competencies, and as the basis for evaluation of the students' process competencies. The Process Analysis must contain a description and analysis of the process experiences obtained by the group during the project period. Furthermore, it should contain proposals for improvement of future project processes. These proposals must be described on an operational level, which can more or less be used as a basis for a subsequent project period. As such, the Process Analysis contains both comparative and vertical reflections. The comparative reflections reflect the qualitative development obtained by the group through explorative and move-testing experiments. The vertical reflections reflect this development in relation to the theories and methods of the course. On this background the Process Analysis is also expected to contain hypotheses of how the group is going to develop in future.

Prior to examination, the students receive a written response to the Process Analysis from the course teacher. It consists of a number of facilitating questions, and the aim is to initiate further reflections by the students. The response is sent to the students, their supervisors and the external censor, and it is used as a discussion paper at the examination.

4. Do the Students learn Soft Skills or Process Competences?

Analysis of students first semester Process Analyzes show that about 1/3 are doing well though not perfect. They describe, analyze and reflect the main areas: project planning and management, corporation and communication and come up with areas where they have experienced specific problems or where they want to improve and how to do it in their next semester. Another 1/3 is in the first semester dealing with problems like planning and management. They start their project with a planning tool, but forget during the semester. Another big issue for them in the first semester is to coordinate and delegate tasks to all students in the group in a fair manner. The communication is not good enough, especially because some group members lack motivation and discipline. If someone in a group is demotivated and undisciplined, the result is that the rest of the group risk losing their motivation and give up on repairing or improving the group work. Another problem is lack of trust in each other, which can lead to conflict. Sometimes a group is able to solve the conflict

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themselves and sometimes they need assistance from a supervisor, but eventually they learn how to do it with no external assistance. The last 1/3 of the groups does not make acceptable Process Analyses. These Process Analyses only reach a descriptive level, without analysis or reflection.

Beside the process analyses, students also have to document their learned process competences in a written exam format. The content is according the goals in the study regulation and is based on knowledge, skills and competences. Each question gives a certain amount of points.

The first part of the exam assignment is based on concrete questions such as (examples):

- Provide examples of group agreement points that aim to ensure that the aspects of importance are not neglected.
- Provide two examples of methods that can be used to analyse or improve group collaboration.

The last part of the exam assignment is based on a case (being in a media company developing apps). The questions are connected to:

- Creativity techniques, project plans and management, teamwork, communication strategies.

Process competences are not easy to learn for all students. 20% are failing their written exam and have to go for reexamination.

The Process Analysis from the second semester is better regarding analysis, reflections and documentation, e.g. about new methods and experiments students have tried out. However, they are dealing with the same problems, though to a lesser extent, and the suggestions for improvements are realistic and well argued. We can see that for some students it is very hard to gain the necessary process competences, either because of their individual preference or because the combination of students in the project groups. Students have experienced that group work has demanded a lot of resources and not allowed any time for developing positive process competences. Some of the students in those groups actually learn a lot, but it is not always visible in their Process Analysis.

The learned process competences are easier applied in the next semesters, but some students still wanted more training of the tools and methods. From a resent questionnaire from third and fifth semester 70% of the students found process competences very useful, but 15% of the students wanted more support for their group work.

These are good results as a survey among Danish companies employing engineers showed that almost 60% found that Aalborg University was particular good at developing engineering educations according to the need of society and companies. In the same survey the three highest ranked qualifications beside the engineering expertise was communication, understanding business models and project management [12].

5. Conclusion

The course in co-operation, learning and project management is arranged with a view to develop the students' process competencies. Through the continuous development of the course we have become aware that the development of process competencies implies the use of several kinds of reflections. The didactic model illustrated in figure 1 is an attempt to understand, which forms of learning that are the most advantageous to the students in this specific topic. From the students process analyses it is visible how the students work with their project and progress their process competencies throughout the semester. Many of the reflections and experiments the students work with during the course are actually leading to an improved practice. It is first of

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all the common sense reflection and the comparative reflection, which is used. The students' Process Analyses indicate that in general, they have difficulties in conceptualizing their experiences.

All students learn how to get a group to function, so they have got a lot of experience using and developing their process competences, but "soft skills are hard to get" as one student said when finishing his Bachelor degree.

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Creating Software Engineering Entrepreneurial Awareness through Hands-On Interaction with Real Entrepreneurs

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Abstract

The fast-evolving technological advances make it easier for entrepreneurs to implement their ideas and reach their users. Because of their training, generally entrepreneurs come from a business background rather than an engineering background. On the other hand, computer science and engineering students are the ones who have the technical skills to develop most of the technology-related entrepreneurial ideas. However, computer science and engineering curriculum usually does not provide room for entrepreneurial exposure. Even the real-world environment is experienced by computer science and engineering students mostly through limited time and scope internships. In this paper, we propose a framework to seed entrepreneurship during computer science and engineering students' studies and to encourage continuation during their professional career. The goal of our proposed framework is two-fold: computer science and engineering students start working in the real-world, experience state-of-art development technologies, and at the same time their entrepreneurial spirit is ignited and maintained. We present several case studies, in which we applied the educational aspects of our framework that led undergraduate and graduate students enrolled in software engineering courses to closely collaborate with real entrepreneurs, and developed software tools that are being used by entrepreneurs to enhance and market their ideas.

Keywords: *Entrepreneurship, Real-world project, Software engineering education*.

1. Introduction

Getting an idea from inception to an actual product is a thorough process. The majority of entrepreneurship student training comes from business schools. Business students learn how to generate an idea and the steps to generate a product, including raising funding, hiring developers, evaluating the product, and marketing it. One of the aspects a business entrepreneur is lacking is the technological know-how to be able to build the actual product, which is generally covered in engineering schools. Some Universities tried to meet these two worlds by creating separate engineering entrepreneurship courses and programs (see for example [1] - [4]). However, the already crowded typical computer science and engineering curriculum does not provide room for entrepreneurial courses. Moreover, accreditation bodies usually focus on evaluating technical aspects of computer science and engineering curriculum, and not on the entrepreneurial aspects. Thus, typical computer science and engineering departments are not incentivized to embed entrepreneurship into their curriculum. Furthermore, computer science and engineering students usually experience the real-world environment only through limited time and scope internships.

In this paper, we propose a framework to incorporate entrepreneurial awareness into the typical computer science and engineering curricula, without changing its focus on technical aspects. On the contrary, our framework strengthens all current technical Accreditation Board for Engineering and Technology (ABET) criteria for computer science and engineering programs [5]. Even though our examples include only software engineering students experiences, our framework can be extended in a similar manner to other engineering disciplines.

The principal step of our framework brings together engineering students and entrepreneurs who have technology innovations. Entrepreneurs provide project ideas to engineering students and agree to spend time in the role of customers. In return, they receive technology prototypes that can be used to further their goal of generating an innovative product. Software engineering students benefit by having a real customer to interact with, a real project to exercise their skills on, as well as learning about other domains, and how their engineering skills can be used in various fields. This gives them real world experience that they would otherwise lack when entering the workforce upon graduation. While collaborating with the entrepreneurs, the objectives of their courses become more meaningful to the students. Teaching engineering concepts by incorporating real-world meaningful entrepreneurial projects not only augments the learning experience but also allows students to work in teams, apply project management, find solutions for interdisciplinary problems, experience innovation, and develop their entrepreneurial potential. On the instructor side, this provides a fresh, interactive perspective in which to teach, and more efficiently convey engineering course information to the students.

We present several case studies, in which students enrolled in software engineering courses closely collaborated with entrepreneurs, and developed software tools that are being used by entrepreneurs' network.

We also present student feedback from interacting with entrepreneurs as well as entrepreneurs' point of view after interacting with the students.

2. Background

A one-semester, junior-senior level undergraduate software engineering course was developed by the second author and hundreds of students have completed projects in the course since 2005 [6], [7]. The first author adapted the educational methodology to a two-semester graduate level software engineering course sequence by incorporating more software engineering content in each of the main phases. The approach follows a Rapid Prototyping lifecycle model and guides the students from a vague half-page project description to a usable software product. The class is split into several teams of five-six students. Teams either compete to provide products for a single project [6], or each team works on their own project [7]. Each project interacts with a real-world customer with a software need. Successful completion of the semester-long project accounts for more than 50% of students' grades in the software engineering course. In addition, upon completion of the project, students demonstrate the use of software to their respective customers and, when customers indicate high levels of satisfaction with the product, team members receive certificates of appreciation from the customer.

Extensions of the approach have been used to generate various results. A mentoring environment between college students and high school students has been discussed in [8]: college students were able to develop software to remotely control a submersible vehicle built by high school students. Benefits of collaborations with the government have been described in [9]: the Federal Aviation Administration supplied a number of high quality software projects for the students to work on. A collaboration with a geographically-distanced University, involving distributed (local-remote) teams has been described in [10]: the team was comprised of the local part (groups of students at each participating institution) and of a remote part (groups of students at the remote institution), and the local-remote parts worked together as a team in developing the projects. Interactions with faculty from fields other than engineering for the purpose of developing software learning tools have been described in [11]: software engineering students developed learning tools used to enhance learning experiences of Biology, Chemistry, and Biomedical Sciences students.

In this paper, we applied the methodology in a truly entrepreneurial environment, in which each real entrepreneurs act as clients in software engineering students' educational setting and in return, the software engineering faculty guides software engineering students in creating software prototypes that can be used by entrepreneurs towards developing their products. The educational objectives include gathering requirements techniques, design methods, implementation standards, and testing tools.

3. Engineering Entrepreneurship Framework Setup

A major difficulty of involving students in real-world projects is finding appropriate projects and collaborators. In our framework, we arranged opportunities with entrepreneurs within mentoring environments, but arrangements can also be made with other small local employers who are active and practicing in leading-edge technologies. The entrepreneurs benefit from receiving free software deliverables which have been designed to suit their needs. Commencing this mentorship early in the student's career allows time to accommodate the phases from concept through prototyping and testing. A complete cycle of development provides students with sufficient knowledge and experience to sustain their effort to bring a product or service to market.

Our proposed framework includes the following general phases:

- **Phase I**: Identify potential enterprising students. Opportunities of working with entrepreneurs are advertised among students at all levels and their selection is made based on their skills and interests.
- **Phase II**: Advertise opportunities for technical collaboration to potential entrepreneurs and ask them to submit descriptions of projects for which they need technical assistance.
- **Phase III**: Select entrepreneurial projects which fit the scope of the engineering courses available.

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- **Phase IV**: Allow entrepreneurs to present their projects directly to the students, who select the projects they will be participating in.
- **Phase V**: Assign students to "entrepreneurial mentors" who will expose them to cutting-edge development technologies and novel ideas, either as individuals or small teams.
- **Phase VI**: Students practice their entrepreneurial skills during regular engineering courses which have projects focused on entrepreneurship. Students may participate in more than one entrepreneurship project, for different engineering courses. Students who participate for the first time get to experience entrepreneurship. Those who already have entrepreneurship experience get to further their entrepreneurship skills and understanding.
- **Phase VII**: Students continue their participation in entrepreneurs' venture either as work-for-hire or as partners, based on mutual understanding and agreements.
- **Phase VIII**: Students develop their own entrepreneurial ideas and create their own companies or collaborations. Students are encouraged to create high-tech ventures in the specially designed technology business incubators associated with their respective academic institutions or localities. The mission of these unique high-tech communities is to foster the development of advanced methods of research, commercialization of ideas and products, and facilitation of technology transfer, education and entrepreneurship in the fields of engineering, the sciences, computer science and business.

Note that some of the phases in the framework may be skipped, combined, or adapted to specific institution needs and constraints.

The partnership between entrepreneurs and the University involves fostering students' entrepreneurial spirit and professional development, instilling can-do attitudes, providing students experience solving real-world problems, and exploring modern technologies and directions of engineering. Results depend more on progress toward the goal and less on having a fully functional deliverable at semester's end. Attitudinal changes evolve from directed training and experience.

Innovation, in this instance, means to perceive a need and conceive of means to fulfil that need in a commercially useful way. Successful innovation results in commercial advantage which can be realized as a direct employee or, perhaps more fully, as an entrepreneur.

3.1. Our Application of Framework

In our paper, we focus on exploring our proposed entrepreneurship framework in software engineering courses. Phases VII and VIII are beyond regular courses and necessitate connections at other levels of institutions, hence we did not explore those phases in detail. The same framework can be used in other engineering curricula, based on the needs of the projects.

In total, 187 undergraduate and graduate students in 24 teams and 16 entrepreneurs with 21 projects participated over the past 6 semesters (since Fall 2012) at Fairfield and Rowan Universities and used our framework.

In order to expose more students to entrepreneurial awareness, in our study we refined Phase I by allowing any student enrolled in our software engineering courses to participate in entrepreneurial projects. For Phase II, we collaborated with the Entrepreneurs Foundation which has a large database of early-stage entrepreneurs, who can be reached via announcements. In addition, the second co-author has access to entrepreneurs through the local IEEE section. For Phase III, we used our experience to select projects that would fit the software engineering course content we are teaching. We did not introduce any bias against entrepreneurs. We selected all projects that fit the courses irrelevant of background of entrepreneurs or evaluation of applicability of entrepreneurs' ideas. For Phase IV, we required entrepreneurs to formally pitch their projects directly to the students. Some semesters students have collaborated across Universities and instead of requiring the entrepreneurs to pitch their projects multiple times, we connected the remote students through live feed so they can ask their questions. We also recorded the pitches so students can evaluate and make a more informed decision on which project to choose. Depending on the location of entrepreneurs, they gave their pitch either in person or remotely. The students were split in teams either before the pitches or after the pitches. In the case when the teams were established prior to the pitches, project decision was made by the team together. Otherwise, students gathered as a team based on their interest in specific projects. For Phase V, once each team of students has chosen its project, they started their interaction with their respective entrepreneurs. For Phase VI, teams of students practiced software engineering methodologies in graduate courses Software Engineering Methods (3 credits) and Software Design Methods (3 credits) at Fairfield University and undergraduate courses Software Engineering I (3 credits) and Software Engineering Laboratory (1 credit) at Rowan University and applied them on the entrepreneurship projects they chose. Phases VII and VIII were beyond the scope of our study because they relied on other aspects of the institution and on entrepreneurs' availability of funding.

3.2. Relationship of Framework to ABET Accreditation Criteria

In this subsection we discuss how our proposed framework enhances the ABET accreditation criteria for engineering education.

At the end of each student's undergraduate engineering education, they need to demonstrate the several capabilities listed below. These capabilities do not have to be captured in a single course, as long as all capabilities are captured in the undergraduate courses required for graduation. Assessment criteria for each of these capabilities are established in each required course that captures a number of them. The following are ABET accreditation criteria:

A. An ability to apply knowledge of computing and mathematics appropriate to the discipline
B. An ability to analyze a problem, and identify and define the computing requirements appropriate to its solution
C. An ability to design, implement, and evaluate a computer-based system, process, component, or program to meet desired needs
D. An ability to function effectively on teams to accomplish a common goal
E. An understanding of professional, ethical, legal, security and social issues and responsibilities
F. An ability to communicate effectively with a range of audiences
G. An ability to analyze the local and global impact of computing on individuals, organizations, and society
H. Recognition of the need for and an ability to engage in continuing professional development
I. An ability to use current techniques, skills, and tools necessary for computing practice
J. An ability to apply mathematical foundations, algorithmic principles, and computer science theory in the modelling and design of computer-based systems in a way that demonstrates comprehension of the tradeoffs involved in design choices
K. An ability to apply design and development principles in the construction of software systems of varying complexity

Our framework meets and enhances the above criteria as follows:

A. Students are able to demonstrate their knowledge of computing and mathematics by developing successful real-world software applications. In addition to course assessment, successful teams are also recognized with certificates of appreciation by their respective entrepreneurs.
B. Initially students receive an overview of the proposed real-world software application they need to develop. They analyze the idea and identify and define the computing requirements for its development. In addition to course assessment, successful teams are also recognized with certificates of appreciation by their respective entrepreneurs.
C. Once the students generate a better understanding of the proposed real-world software application, they design, implement, and then evaluate the application to meet the entrepreneurs' and their users' needs. In addition to course assessment, successful teams are also recognized with certificates of appreciation by their respective entrepreneurs.
D. One of the main criteria of being able to operate as a software engineer is to be able to work as part of a team and to be able to contribute to the project without overlapping with your teammates. In our software engineering courses, we split the class in teams corresponding to the difficulty of the real-world software application they need to develop. Teams would not be able to achieve their common goal, which is to finalize the project, without team participation and coordination. In addition to course assessment, successful teams are also recognized with certificates of appreciation by their respective entrepreneurs.
E. By interacting with the entrepreneurs and by understanding the role of the real-world software applications they are developing, students are exposed to professional, ethical, legal, security and social issues and responsibilities.
F. Students are able to build successful software applications only by communicating effectively with a range of audiences, including entrepreneurs, faculty, local/remote peers, and even potential users of their software.
G. While interacting with the entrepreneurs and building real-world software applications, students realize the local and global impact of computing on individuals, organizations, and society.
H. In our software engineering courses, students learn current techniques and then skilfully apply them for the computing practice by building real-world software applications. Students also learn state-of-the-art tools necessary for the development of their applications, including version-control tools.
I. When building innovative real-world software applications, students have freedom of design choice. In addition to course instructor evaluation, their algorithms and designs are also evaluated by their respective entrepreneurs.

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J. The complexity of real-world software applications students' are building is not trivial. Hence, in order to be successful, students need to properly apply design and development principles based on the complexity of their projects.

In our software engineering courses we were able to incorporate Phases I-VI of our framework, which allows us to capture *all* capabilities required by ABET accreditation in *single* courses.

4. Sample Projects

In this section we present several projects proposed by entrepreneurs. Since some of these projects are still at various stages of development, for confidentiality of idea purposes we cannot present more of these projects.

We solicited projects through co-authors' contacts and institution alumni as follows: the first co-author solicited projects through Fairfield University alumni, the second co-author solicited projects through Rowan University alumni as well as through the IEEE-CT Entrepreneurs Network, the third co-author solicited projects through the Entrepreneurship Foundation which is a non-profit organization headquartered in Fairfield, Connecticut, USA. The Foundation works closely with startups and early-stage companies to promote economic development and job creation. The typical company we approached had less than 10 employees, which makes the communications easier and faster (not the bewildering array of layers of bureaucracy and delays in decisions and interim approvals often encountered when attempting the same relation with a large enterprise). Also, we assumed, and the results proved correct, that small companies are more likely to be willing to spend time with students and employ recent grads. Some students who developed software packages were then hired by the client companies to embellish and maintain the products.

The types of projects solicited included:

- Software project development
- Website development
- Mobile app development

Projects were pre-screened by co-authors to conform to a level of sophistication and workload to challenge the students, yet of a complexity that would not require more than one or two semesters to complete. The intent was for the students to be able to complete a project that they could list on their resumes, as opposed to merely completing a portion of a larger undertaking.

In addition to experiencing working with entrepreneurs, the provided real-world projects were useful for the job experience, building business references, and experience working on a project as a member of a team (project management), working for a client (requiring competent communications skills), and software development.

One of these software tools, the Capital Source application, addresses the opportunity to provide an entrepreneur a solution to develop an idea and the means to tackle the needy and unanswered solution in the present world of technology. The tool brings in both aspirants and companies to a common platform for a better and more precise way of communicating among them. Users of this tool have a flexibility to choose among various fields of interests and participate in entrepreneurial competitions which are organized by companies with reputation or award the winners with prize money.

Another software tool, Entrepreneurship software, is meant to help with the first step for any individual or team interested in creating their own business. Someone looking to open their own business might find it difficult to know where to look for support. This tool compiles those opportunities and makes it more accessible to the user. It has been said that small businesses are the future of many economies as they are the ones who are creating jobs and other opportunities. The tool is a free resource to search information that ideally leads to the rise in the number of businesses and to economic growth.

5. Student Survey

Our focus group consisted of students taking the Software Engineering courses at Fairfield University and Rowan University in the last three years. These courses are major courses for credit for upper undergraduate and graduate students, part of the Computer Science and Software Engineering curriculum. Generally, they cover the methodologies, techniques, and tools needed to successfully gather software requirements, and perform design, implementation, testing, and maintenance. Each of these classes included a project component to reinforce the concepts taught.

Seventy students responded to our survey. The aim of the survey was to capture students' point of view related to the collaboration with entrepreneurs for the class projects. The intent was to find how the collaboration motivated or supported their learning and entrepreneurial spirit and what issues arise when working with partners outside school. Student survey results are comprised in Table 1.

Table 1. Survey of students participants in our application of framework.

Question	Percent of students choosing agree and strongly agree
Did you enjoy project based learning with entrepreneur partners?	91.47%
Did you enjoy working in groups?	82.86%
Do you feel that you mastered learning objectives through project based learning more than you would have through traditional instruction?	86.96%
Did interactions (student-to-student, student-to-teacher, student-to-entrepreneur) support the learning process?	88.57%
I believe I learned more by working with entrepreneurs	74.29%
I believe I improved my communication skills as a result of interaction with the project partner(s) for the project	80.00%
Did the project partner(s) respond to your questions and concerns in a timely manner?	78.26%

The survey was anonymous and included twelve questions. For most of the questions, a Likert scale was adopted for the choice of answers. The survey results show that a high percentage of students preferred to work with entrepreneurs for the class projects. Over 91 percent of the students enjoyed project based learning with entrepreneur partners. However, only 83 percent enjoyed working in groups, with most of them describing team coordination as a difficult task. Some other challenges that the students faced during the collaboration were mentioned such as time management, different technical abilities, and adjusting to various level of instruction as many students are still expecting to get their instruction from the professor instead of the entrepreneurs or team leaders. Several questions investigated if the students' performance was affected by the fact that they were working on a real-world project with entrepreneurs. For instance, 87 percents felt that they mastered learning objectives better through project based learning than through traditional instruction. One question inquired information related to the interaction (student-to-student, student-to-teacher, student-to-entrepreneur) and if it supports the learning process: 89 percent of the students agreed or strongly agreed with this statement.

Some other factors considered were technical knowledge on the customer side and communication problems with the customer. 78 percent of students were happy with the way the entrepreneurs responded to their questions and concerns most of the time in a timely manner. 80 percent of the students believe that they improved their communication skills as a result of interaction with the entrepreneurs and about 75 percent believe they overall learned more by working with them. While some students said that they would have liked to spend either more time or less time with the entrepreneurs, the majority (80 percents) considered that they spent about the right amount of time with their partners.

The students were also asked to suggest their own thoughts in free response questions. Students wrote that the best part was simply "interacting with entrepreneurs", "getting to work with real-life scenarios and business ideas", or "learning new technologies". One student concluded that working with entrepreneurs "forces you to think about your work from a different point of view to achieve your goals" while another student expressed his satisfaction on "working with other people to come up with ideas".

Overall, despite the fact that managing expectation was different from one entrepreneur to another, the group collectively was more interested in working with entrepreneurs because they gave an insight into the real problems and the solutions to them including not only the technical aspects but also the business process, while the consent was that real-world projects with entrepreneurs provide a much richer learning experience than in other classes with projects.

6. Entrepreneur Survey

To evaluate our program from the standpoint of the clients, we conducted a survey of the contact person at each company, generally the CEO, as to their experience with the program, overall satisfaction, and recommendations for improvement. We were able to gather responses from six of the entrepreneurship companies we worked with. Some entrepreneurs could not be reached and others are currently in progress and were not included. A Likert scale was adopted, with 1 to 5 as the choice of answers. Entrepreneur survey results are comprised in Tables 2 and 3.

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Table 2. Survey of entrepreneurs participants in our application of framework. Table shows the relationship between entrepreneurs knowledge of software development and satisfaction with outcomes.

Entrepreneur	How would you rate your own software development acumen	How likely is it you would recommend the service to other entrepreneurs
A	5 Expert developer	5 Extremely likely
B	5 Expert developer	5 Extremely likely
C	3 I have some understanding of process	4 Very likely
D	3 I have some understanding of process	3 Probably
E	2 I have little understanding of process	5 Extremely likely
F	1 Almost no knowledge	1 Extremely unlikely

Many of the participating companies were small entrepreneurial firms without an IT department or developer on staff. In our survey we found an interesting correlation between knowledge of the client and the client's satisfaction with the work. The explanation may be that clients who do not appreciate the difficulty and time requirements for software or web development, may have unrealistic expectations, and therefore more likely to be disappointed. The company ratings, while already quite good, could be raised still further by selecting more sophisticated clients or by better managing expectations; that is, better explaining to clients a realistic level of quantitative and qualitative performance. Even though we did try to manage clients' expectations beforehand, it appears that their eagerness to obtain usable products overcame our appeals. In addition, entrepreneurs with little technical background and funding were at the end of the semester suddenly faced with a software product they didn't know how to manage. We also had few teams which weren't able to complete their tasks. A technical client would have been able to take the parts those students developed and further enhance them. A non-technical client would feel that nothing was accomplished and their time was not well spent.

There is almost a perfect correlation between entrepreneur technical acumen and their satisfaction (see Table 2). The one outlier, client E, admitted: "The scope of the work I had in mind was too ambitious for their skills and unrealistic to expect on my part. It took a while for us to sort that out. I would like to try it again, now that I have had the experience." Thus, confirming the need to better manage client expectations up front.

Table 3. Survey of entrepreneurs participants in our application of framework. Table shows entrepreneur rating of specific student skills.

Rating of students	Mean
Business deportment (Professionalism)	3.8
Agility (adapting to spec changes)	3.7
Communication skills - Written	3.7
Organization (Project Management)	3.7
Responsiveness to your questions	3.7
Coding skills	3.5
Communication skills - Oral	3.5
User interface skills	3.2
Business knowledge	2.8
UI Design skills (look and feel)	2.8

When evaluating the entrepreneur rating of specific student skill we found that the lowest scores were for UI Design and Business Knowledge (see Table 3). The lack of business knowledge is understandable, these being computer science and software engineering students. This reinforces our goals of exposing students to entrepreneurship. The deficiency in UI Design skills is a weakness we plan to address in subsequent offerings.

Note that one entrepreneur consistently rated the students "Poor" in every aspect, which is unreasonable. Clearly this client was unhappy. The interesting take-away is that they also rated their own software acumen as 1 on a scale of 5 "Almost no knowledge." Again supporting the conclusion that the program works best with knowledgeable clients, or ones who have been clearly notified as to what they should expect to be accomplished by a small team of students in a one or two semester class. Removing the outlier from the data, the mean scores would have been 10% higher, ranging from 3.2 to 4.2.

Based on feedback from entrepreneurs we conclude that the program works, delivering free software, web and mobile app prototypes to young companies that cannot afford market rates, while providing students with resume quality experience and business contacts.

6. Conclusion

In this paper we have presented a novel framework for igniting engineering students' entrepreneurial spirit. Our study focused on incorporating entrepreneurial experiences within existing engineering technical curricula, because most engineering schools do not have the capability of incorporating specific entrepreneurship courses or programs. Even though our proposed framework can be applied to any engineering curricula, we gave examples of software engineering experiences and provided details of case studies involving entrepreneurs with software needs and students enrolled in software engineering undergraduate and graduate courses.

While innovation and entrepreneurship are widely held to be of rapidly increasing importance, regularized training to focus on such roles has not become widely available. The students who participated in our program have the experience and confidence to pursue entrepreneurial paths early and at a higher level in their careers, than their counterparts who miss out on this opportunity. Student feedback confirms that participating students gained valuable experience and insights and had a maturing effect.

Maintaining student entrepreneurial prowess is another important aspect of empowering successful entrepreneurs. In our study, we strived to encourage students to continue on an entrepreneurship path, including further mentoring and hiring by the entrepreneurs with whom they collaborated. However, these efforts are currently limited by the fact that they are beyond college curricula and that the early-stage entrepreneurs we collaborate with do not have many resources. To alleviate these limitations, in the future we will try to connect entrepreneurial students with various resources for entrepreneurs, including seminars, talks, and incubators.

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Preparing Mechanical Engineering Design Students for Computational Fluid Dynamics Code Development

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Abstract

CFD is now a useful tool for mechanical design engineers. CFD has also gained a broad acceptance in engineering education, and has been adopted at undergraduate and postgraduate level course in many universities. The teaching of CFD at the undergraduate level however usually focuses on giving students an understanding of the numerical methods and details involved, supported by what are little more than code fragments, followed by learning an abstract form of CFD skills and processes, without any real interaction with the complex core computer coding behind what is often just "easy-to-use" or "push button" commercial interfaces. Quite often, as the student progresses in his/her use of CFD, especially in the research area, it becomes clear that an "off-the-shelf" commercial CFD package is not able to satisfy all requirements to simulate a given problem fully, nor to obtain accurate results. Code development has to be undertaken to enhance the commercial code's capabilities with the insertion of say additional FORTRAN coding or through MATLAB. The purpose of this paper is to outline what must be taught to add computer coding to what usually is a well protected, though capable of being compiled and linked, core computer code so that the complexity of interacting is lessened and better understood.

Keywords: Computational fluid dynamics, Code development, Mechanical engineering

1. Introduction

Computational Fluid Dynamics (CFD) can provide detailed characteristics of the pressure, velocity and temperature fields as well as information concerning the distribution of species for a wide variety of geometry and applications. With the rapid growth of powerful computer resources and the development of well optimized and reliable commercial packages, CFD is now a useful tool for mechanical design engineers [1]. Projects involving design, especially in the thermo-fluids area, now routinely involve the use of CFD, CAD, Rapid Prototyping and testing in aerodynamic or hydraulic facilities [2].

CFD has also gained a broad acceptance in engineering education, and has been adopted at undergraduate and postgraduate level course in many universities [3]-[5]. However, the teaching of CFD at the undergraduate level usually focuses on giving students an understanding of the numerical methods and details involved, supported by what are little more than code fragments, followed by learning an abstract form of CFD skills and processes, without any real interaction with the complex core computer coding behind what is often just "easy-to-use" or "push button" commercial interfaces.

Quite often, as the student progresses in his/her use of CFD, especially in the research area, it becomes clear that an "off-the-shelf" commercial CFD package is not able to satisfy all requirements to simulate a given problem fully, nor to obtain satisfactory accurate results. Code development has to be undertaken to enhance the commercial code's capabilities with the insertion of say additional FORTRAN coding or through MATLAB. This is usually not an easy procedure, as commercial codes are not usually open source but do allow 'add-ons' as substitutes to the protected core computer coding. Care must be taken to ensure that the student has all the necessary knowledge and skills to proceed.

The purpose of this paper is to outline what must be taught to add computer coding to what usually is a well protected, though capable of being compiled and linked, core computer code so that the complexity of interacting is lessened and better understood, the added coding is in fact correct, and, efficient and reliable results are obtained from the enhanced commercial package. The results of a survey of participants specific to this part of a CFD course undertaken by mechanical engineering design students are also presented.

2. Method of Interfacing

Generally, current developments are the integration of two computer packages, which allows a scripting programming package to combine with a computational fluid dynamics package to enhance pre-processing, model manipulation and post-processing, as indicated on Figure 1. This is a two-way process where, for example, functions within the script programming package can be imported into the CFD package for use, or, models from the CFD package can be exported to the scripting programming package for further use say in the control area. An example of the integration can be found in Ramadesigan *et al*. [6].

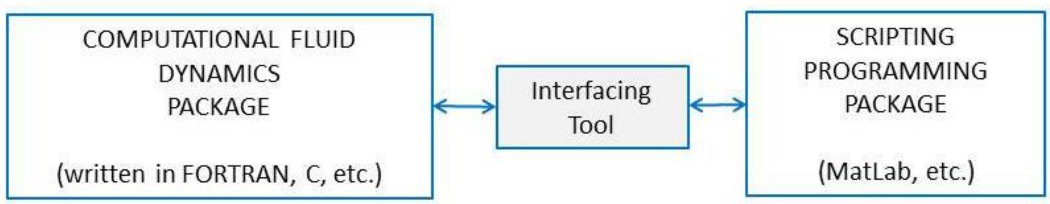

Figure 1. Two-way integration of CFD and scripting programming packages.

The work here however, is not intended to give full integration of two packages, but rather to enhance the capability, and importantly the accuracy of a commercial computational fluid dynamics package and to devise a learning curve to achieve this in an efficient and rewarding way. There are many areas of a commercial CFD code which could be changed with the view to improvement, for example, by adding a faster, more efficient new numerical solving technique, or, by improving the method of closure of the momentum equations. It is the latter which is chosen here to give a framework to build on.

Closure of the momentum equations is necessary as the equations used in current CFD packages are averaged, which introduces extra unknowns into the equations. These extra unknowns are accounted for by Reynolds-Averaged Navier-Stokes (RANS) turbulence models [7] [8], a good variety of which come as standard with a commercial code. Closure using the more recent and increasingly preferred Large Eddy Simulation (LES) [9] [10] is however, not found in all commercial codes, and this together with the fact that LES is currently a strong research topic, makes it a good candidate to teach students how to introduce computer coding into a commercial CFD package. The method of enhancement of the commercial code used here is summarized on Figure 2.

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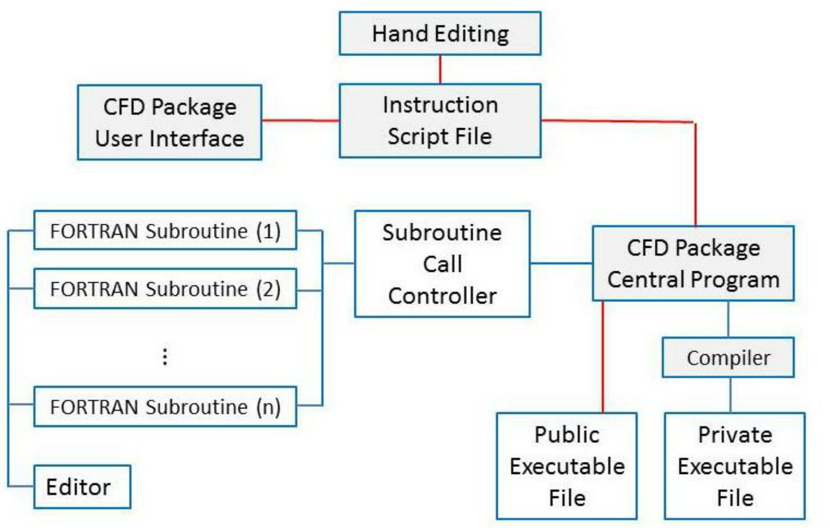

Figure 2. The overall structure of the computational fluid dynamics package capable of being re-compiled.

The above computational fluid dynamics package can be run without having to be compiled, i.e. no new FORTRAN coding has been added (or overlaid) to the CFD package central program and the 'public' executable file is used to obtain results for post-processing. When FORTRAN coding is added to any of the FORTRAN subroutines shown by the user then the central program does have to be compiled and linked. To protect the original CFD package from being changed, and perhaps corrupted, a 'private' executable file is produced and used.

3. Instruction Delivery

It was thought convenient to introduce the method of code development by way of a computational fluid dynamics project, dealing with the simulation of turbulent vortex shedding from a cylinder investigated using Large Eddy Simulation (LES) as the closure method instead of the more conventional Reynolds-Averaged Navier-Stokes (RANS) turbulence models. However, before embarking on this fairly ambitious project, students needed a thorough grounding on the topics summarized on Figure 3. Of the topics shown on Figure 3, those not already covered in the existing mechanical engineering design students undergraduate course were, *Introduction to Large Eddy Simulation*, *FORTRAN Language Course* and *Interface Method*.

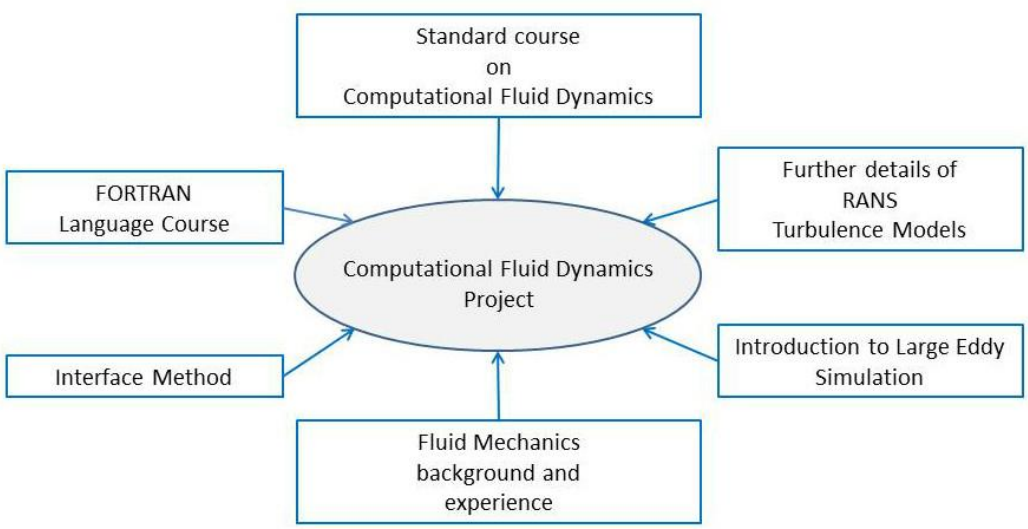

Figure 3. Topics necessary for students to know before enhancing a CFD package.

In the *Introduction to Large Eddy Simulation* module, which had a length of six hours, the idea of using filtered continuity and momentum equations so as to explicitly simulate the large scales of a turbulent flow while modelling the small scales was introduced [11]. A filtered kernel, which is a localized function, can have several shapes, e.g. a Gaussian filter, a box filter or a cut-off filter [12], was discussed. It was shown that on applying filtering to the Navier-Stokes equations a set of equations similar to the RANS equations was obtained, and a non-linear analog term to the Reynolds stresses of RANS was shown to be produced. This term, the sub-grid (SGS) Reynolds stress must be modelled, and it should be remembered that this is not a physical stress but rather the large scale momentum flux caused by the action of the small or unresolved scales. The approximation of the SGS is the main topic of LES and it originates the different types of LES models. In this work, the Smagorinsky closure model [13] was used. This is one of the most commonly LES models employed nowadays. Making an analogy with the effects of stress in laminar flows, the SGS can be written in terms of the strain rate in the resolved velocity field and by dimensional analysis, it can be proven that this is a reasonable form of the eddy viscosity to effect closure of the momentum equations. This form however is known to vary with Reynolds number and so additional treatment is required. One approach, and the one used here is to include van Driest damping to reduce eddy viscosity when required.

In the *FORTRAN Language Course*, which also lasted six hours, the basics of the procedural computer programming language was first introduced and these were built on with hand-on programming exercises. Students actually found this course reasonably easy, as they had already competed computer programming modules of object orientated programming and scripting programming. The later exercises concentrated on writing code suitable for solving discretized equations, an important part of CFD coding.

Four additional hours were spent introducing the students to the *Interface Method* based on the scheme set out on Figure 2. This was very practical module where students learned, for example, to overlay existing formula for the ideal gas and set non-standard sources by the use of an Input Language script which is part of the commercial CFD package.

4. The Project - Flow Over and Downstream of a Square Cylinder

The computation carried out was in a domain corresponding to that for the Workshop on LES organized by Rodi and Ferziger [14] as shown on Figure 4.

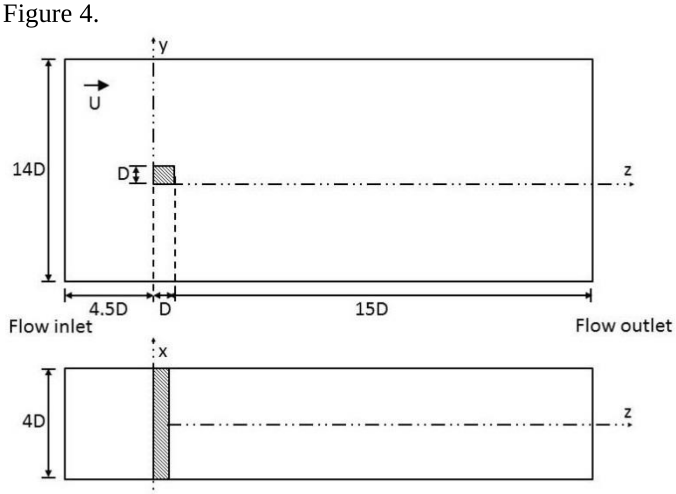

Figure 4. The geometry of the square cylinder flow.

Both 2D and 3D simulations were performed. Three-dimensionality of turbulence cannot be questioned and it has been stated [15] that 2D LES calculations are clearly inferior to the 3D ones since certain important features of turbulence are not resolved, for example the vortex formation in the spanwise direction. However, some authors [16] have concluded that by means of a denser 2D grid the quasi-two-dimensional mechanism can be accurately evaluated, mainly in the regions closest to the solid walls. Due to lack of computer power and keeping in mind that the goal here is to teach and learn rather than simulate real engineering projects, it was concluded to evaluate the

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vortex shedding due to the square cylinder using 2D simulations only, as these are much more economical. There were several levels of mesh size used in the calculations, so reinforcing the good CFD practice of obtaining solutions with mesh size independence. The maximum number of grid nodes used was 1.5 x 10^4. A typical grid is shown on Figure 5.

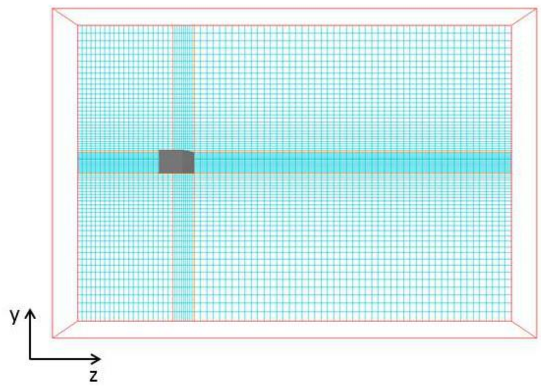

Figure 5. Cartesian computational grid used for the present project.

For the convective and temporal discretization, a second-order Van Leer scheme was selected for simulating the convective transport in the momentum equations, and, a third-order Adam-Moulton scheme was implemented for time. The flow was simulated only over 50 time steps, again due to lack of computer power.

The computational domain geometry, material properties, initialization and numeric were all set up for the current project using the normal CFD computer package User Interface mention on Figure 2.

The FORTRAN computer code needed to be written by the students in this project was for the discretized Smagorinsky sub-grid model which would calculate the eddy viscosity needed for closure of the momentum equations. The code was first written using a FORTRAN Integrated Development Environment and checked for syntax errors. The students were given the relationship between the eddy viscosity and the rate of strain tensor, together with the fairly lengthy discretized form of the rate of strain tensor and asked to write the FORTRAN coding based on the standard finite volume grid cell notation which would return a value for the eddy viscosity. This LES sub-grid model would be the one which would overlay the standard RANS models found in the commercial code.

The FORTRAN coding written by the students was then transferred to one of the Subroutine modules listed on Figure 2, and appropriate instructions were written for the inclusion of the sub-grid model and relayed to the CFD Package Central Program using the Input Language script. This was followed by compilation and linking the new CFD package so producing a private executable file ready for solving.

Typical results found by the students for streamlines in the near-wake of the cylinder are shown on Figure 6. Students were then strongly encouraged to find experimental measurements in the literature for comparison to ensure that their simulation was of reasonable accuracy.

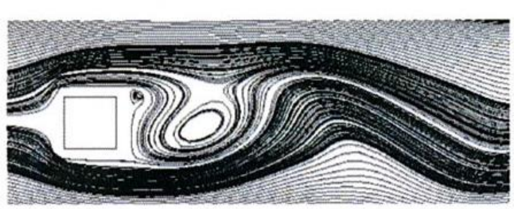

Figure 6. Streamlines calculated using LES simulation in the near-wake of the square cylinder.

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5. Online Questionnaire

An anonymous online survey (Table 1), in the form of a questionnaire was conducted for students (N = 43) concerning the preparation for CFD code development module. The questionnaire consisted of 10 statements with which students could, strongly agree, agree, neutral, disagree and strongly disagree plus a column for no opinion. Comments were encouraged to help understanding of why they responded as they did.

Table 1. A list of questions/statements used in the survey for students' feedback

No.	Question/Statement
1	I found the standard CFD computer package easy to use.
2	I found the FORTRAN computer programming easy.
3	I found interfacing the FORTRAN coding with the CFD package easy.
4	The skill of enhancing a commercial CFD package will be useful to my later studies.
5	The theory of CFD is easy.
6	The skills of CFD are easy.
7	CFD gives me a much better understand of physical phenomena.
8	I feel I can relate CFD to some physical situations.
9	I feel I am in a position to do 'real' engineering projects using CFD.
10	I would recommend this CFD course to others.

Generally, student feedback surveys have a very low response rate [17, 18]. However the response rate here was high (>70%) and overall, the results from the survey were positive. The responses to the survey are shown on Figure 7 and indicate that students felt that they benefited both from using CFD packages in general and from learning the particular skill of enhancing a commercial CFD package.

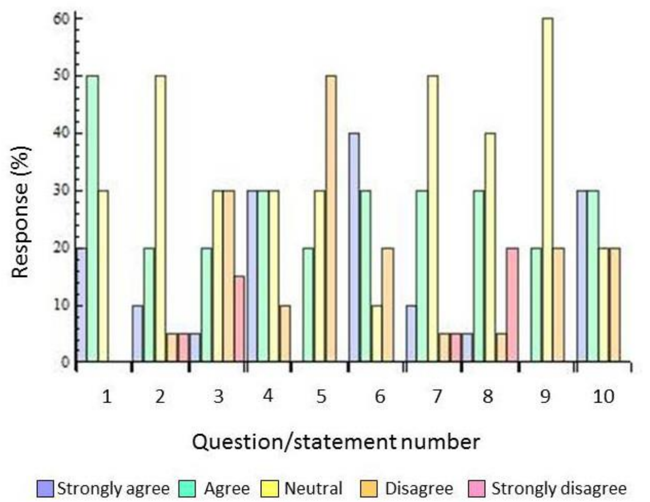

Figure 7. Chart showing survey results.

From Figure 7 it is clear that this cohort now finds the use of the standard CFD package reasonably easy, but is fairly neutral in finding the FORTRAN computer programming easy. As may be expected, the students are still not confident about the extensive theory and knowledge underpinning CFD, but are very comfortable applying the skills. There is still a reluctance to think they are prepared for 'real' engineering projects. This would actually normally not happen immediately in a professional engineering office where the norm would be that newly graduated engineering would be teamed up with more experience staff. There was a reasonably positive view by the students to the course as a whole, based on the response to question 10.

In additional comments, the students expressed the view that with some practice, it was reasonably easy to use the standard commercial CFD package but that the results obtained always needed validation. They did say that this latter part was not always easy to do, as a literature search could take a long time to find suitable experimental results on which to base the validation. Regarding the enhancement of the existing commercial CFD package, there

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was general agreement that this was an involved and intricate process and needed special concentration and a detailed knowledge of both FORTRAN and how to implement the extra coding into the standard CFD package. Generally they felt the process needed to be repeated many times before they were fully confident. However almost everyone saw the use and value of knowing this process, especially if they were to make a novel contribution to future research.

6. Conclusions

A process has been devised to allow students to enhance the capabilities of a commercial CFD package by the insertion of computer coding to allow some novel method of calculation not already built-in to the existing package. In this way students can use the capabilities of what is usually a highly optimized and reliable computer package, which has been built up over decades on occasions, with new and inventive ways of solving thermo-fluid problems.
The project chosen here as a framework for the teaching and learning was fairly ambitious, in that the method of closure of the momentum equations was much different from those the students had already been shown, and although the students found the preliminary FORTRAN instruction and assignment work quite easy, the extra FORTRAN coding necessary for completion of the project was reasonably difficult and detailed for undergraduate students to complete.

However as can be seen from the survey above, the students were reasonably comfortable with the process, which would indicate that they found the learning curve reasonably easy generally, but with occasional large challenges.

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A Spreadsheet-based Model of Light Reflection on Thin Layer to Improve Understanding of Optical Phenomena

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Abstract

Optics, as well as other areas of physics, has numerous applications in engineering. In addition to the construction of optical devices and instruments, such applications include a number of measurement methods based on optical phenomena. Prime examples are the decomposition of white light into the colour spectrum, the formation of interference patterns, or polarization of light. We encountered an interesting engineering problem while studying reflection of light on a thin layer formed by macromolecules of polyunsaturated isopropyl-acrylamide. Thickness and structure of this material varies depending on the temperature and pH of its immediate environment. A monolayer microgel is sandwiched between two thin metal layers, typically gold, that act as semitransparent mirrors. In principle, such thin layer device can be used to develop a contact probe to measure the temperature and/or pH of soil.

The microgel etalon can be used as a device to improve understanding of light interference in advanced engineering courses. Students are provided experimental data measured on such a thin layer using a spectrometer, along with the spectrum of the light source prior to reflection on the thin layer. Their task is to create a mathematical model of the observed optical phenomenon. The model is to be implemented using a spreadsheet that calculates the interference of the reflected beam on both semitransparent mirrors for individual wavelengths. Relative intensities obtained this way can be plotted on a graph and compared to the graph obtained experimentally. The students have to create a model that best corresponds to the measurements. This empirically formulated solution to the complex problem of light interference by reflection on thin layer leads to a deeper understanding of the phenomenon compared to a classical simplified model from introductory courses in general physics, i.e. from theoretical model derived through deduction.

Keywords: *physical model, optical phenomena, thin layer reflection, mathematical model, spreadsheet, understanding*

1. Introduction

Engineering profession is based on application of the principles of mathematics, physics, chemistry and other related applied subjects. As such, engineering graduates must have deep understanding of a number of phenomena encountered in engineering applications that are rooted in these principles. One possible approach is to engage students in experimentation with actual and simulated devices that use specific principles for their operation.

In this article, we consider an interesting problem of light reflection on a thin layer. Informed by our research, we encountered a device that uses thin layer formed by macromolecules of polyunsaturated isopropyl-acrylamide to develop a contact sensor to measure the temperature and/or pH of soil [1]. A monolayer microgel is sandwiched between two thin metal layers, typically gold, that act as semitransparent mirrors. Thickness and structure of the thin layer material varies depending on the temperature and pH of its immediate environment, making it possible to derive the changing soil parameters by measuring the spectra of reflected light.

While the real sensor devices are inexpensive and at our disposal, their potential for demonstrating the phenomena of thin layer reflection is rather limited. The use of actual sensor etalons requires a sophisticated laboratory setup including a well-defined light source and a spectrometer. In addition, measuring changes of optical properties of the device under different conditions is quite time consuming as it requires adjustment of acidity of a solution in a tank where the etalon is located.

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Alleviation of the above mentioned issues is one motivation for the development of the model described in this contribution. Another, even more important reason is to provide students with a tool that can improve their understanding of the underlying phenomenon through its interactive modelling [2]. The availability of such tool will motivate students to do research of the physical phenomena [3] and verify hypotheses [4] they make about the behaviour of the system. Using the model, they can vary parameters of the device and immediately see the effect on its optical properties [5].

2. Background

The device considered in this study is composed of two gold layers forming semitransparent mirrors that reflect fraction of the incident light back to the source. The layer between the two mirrors is very thin (i.e. its thickness is comparable to the wavelength, λ, of the incident light) and thus the phenomenon of *interference on thin layer* takes place [6].

To briefly explain this phenomenon, consider the simplified diagram of the device in Figure 1. There are three environments, with refraction indexes n_1, n_2 and n_3. The semitransparent mirrors are formed by depositing a thin layer of gold at the interfaces between two different environments. The material in the middle forms a thin film with defined width L. The thickness of this layer must be comparable to the wavelength of light of interest.

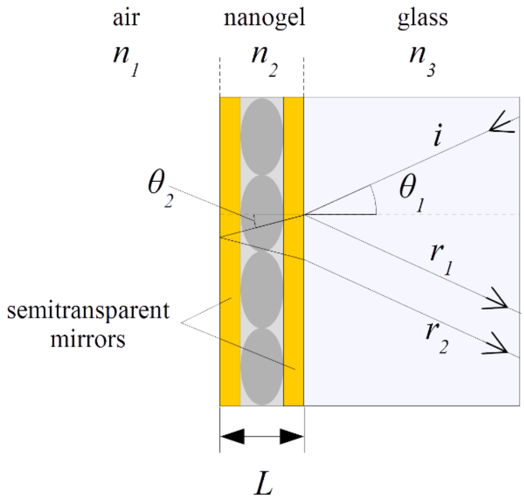

Figure 1. Structure of the device

An incident ray of light, i, intersects the first semitransparent mirror at an angle θ_1. Part of the light is reflected back to environment 1 as ray r_1. The remaining light continues to environment 2 at a new angle θ_2 given by the *law of refraction*. Another reflection takes place on the second mirror, and part of the light returns back toward environment 1 as ray r_2.

As the waves of the two are moving in parallel towards the observer, they are added together. Since ray r_2 passes through environment 2, it follows a longer path and thus could be out of phase with respect to ray r_1. As a result, both waves are added together with different phase shifts. If the phase shift is zero, then observer sees light with relatively higher intensity. On the other hand, with phase shift of 180 degrees the observer detects relatively lower intensity, because the waves cancel each other.

This property is summarized in the following equation. It calculates the amplitude c of the sum of two sine waves of the same frequency, with amplitudes a and b, and phase shift of φ

$$c = \sqrt{a^2 + b^2 + 2ab\cos\varphi}. \tag{1}$$

To evaluate the intensity of the reflected light, one must compute the phase difference of the reflected waves. In order to do so, two additional properties of reflection must be considered. First, waves travel slower in environments with higher index of refraction. Second, a reflection causes a phase shift of 180 degrees, if the

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refraction index of the material that reflects the light is higher than that of the environment from which the light enters.

Consider the case of reflection of light perpendicular to the mirror, and assume that the extra distance travelled by ray r_2 is equal to $2L$. The path difference pd of ray r_2 can be calculated as

$$pd = 2Ln_2. \tag{2}$$

This path difference can be converted to phase shift φ by comparing it to the wavelength λ of the light

$$\varphi = \frac{pd}{\lambda} 2\pi. \tag{3}$$

If there is a phase shift on either of the two mirrors, it must be included into (3) by adding π. This equation can be seen as a function of λ that corresponds to the spectrum of the reflected light. Its amplitude is proportional to the cosine of λ^{-1} which means that the reflected spectra form an interference pattern. The positions of maxima can be located by find wavelengths where the values of cosine are maximal. This translates to phase shifts equal to the multiples of 2π

$$2\pi m = \frac{pd}{\lambda} 2\pi, \tag{4}$$

and thus

$$\lambda = \frac{pd}{m}. \tag{5}$$

If there is a phase shift caused by reflection the last equation changes to

$$\lambda = \frac{pd}{m+0.5} \tag{6}$$

This theoretical result can be confirmed by measuring actual reflected spectrum of the device. The spectrum shown in Figure 2 was measured by spectrometer Ocean Optics USB2000+ using white light source HL-2000, in a solution with pH of 3.23 at temperature of 25°C.

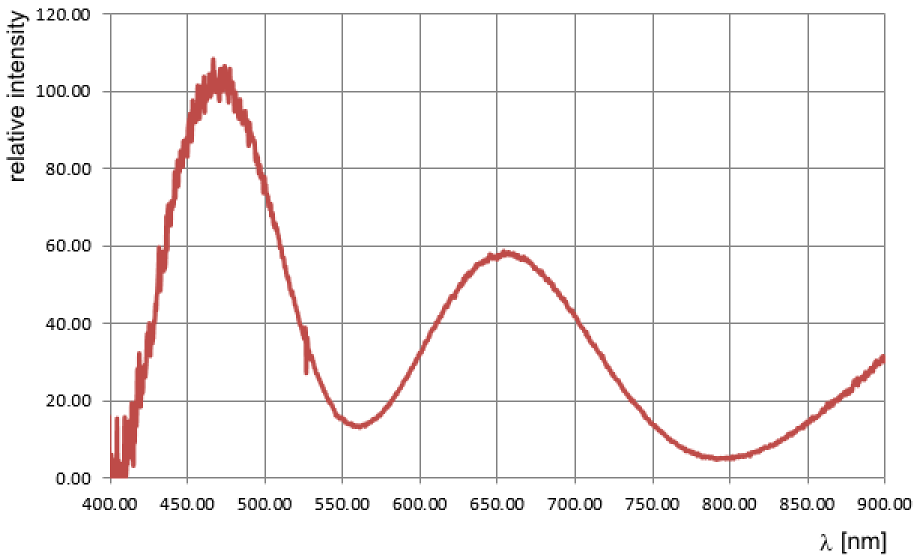

Figure 2. The spectrum of the reflected light measured with spectrometer

There are two apparent maxima visible in Figure 2. To determine which maxima are plotted, one can exploit the existence of the unique ratio r_m of positions of two consequent maxima λ_m and λ_{m+1}

$$r_m = \frac{\lambda_m}{\lambda_{m+1}} = \frac{m+1.5}{m+0.5}, \tag{7}$$

where

$$\lambda_m = \frac{pd}{m+0.5}, \tag{8}$$

and

$$\lambda_{m+1} = \frac{pd}{m+1+0.5} \tag{9}$$

For m = 1, 2 and 3, the values of r_m calculated from (7) are, respectively, 1.666, 1.4 and 1.286. This ratio is constant and does not change with L. Therefore, it can be used to determine which interference maxima are plotted. For example the maxima in Figure 2 are located at 660 nm and 470 nm. The ratio of 660 and 470 is 1.404 and, therefore, one can conclude that the maximum on the right corresponds to m=1 and the maximum on the left to m=2.

3. A Spreadsheet-based Model of Light Reflection on Thin Layer

A model of the physical phenomenon of light reflection on the two semi-transparent mirrors and interference of the reflected light for different wavelengths was built to implement the theory described above. For simplicity, the computer model assumes that the index of refraction is across all three optical layers constant and independent on the angle of the ray passing through given layer. This assumption is correct for both boundary layers formed by the glass substrate and the layer of air. However, it may not be sufficiently accurate also for the middle layer formed by the macromolecules of polymer polyunsaturated isopropylacrylamide that are roughly of spherical shape (at a microscopic scale). Such a layer may optically behave in a different way than a conventional thin layer bounded by two parallel planes.

Another simplification stems from neglecting the refraction of light on the semi-transparent mirrors formed by very thin layers of gold. With respect to the wavelength of visible light, gold (similarly to the polymer macromolecules) does not form a continuous layer, but rather a thin grid that partially reflects light (according to the law of reflection) and partially transmits it. The question remains whether the transmitted light continues exactly in the direction of impact on a layer of gold, or whether its direction is influenced by its crystal lattice.

More adjustments were applied to the model after the implementation the first, simple model described above. In this model, the amplitude of individual wavelengths did not correspond to the measured values well. Therefore the second, more accurate model uses correction based on the assumption that the reflectance of the semitransparent mirrors is not constant throughout the visible spectrum, but varies exponentially with the wavelength of the incident light.

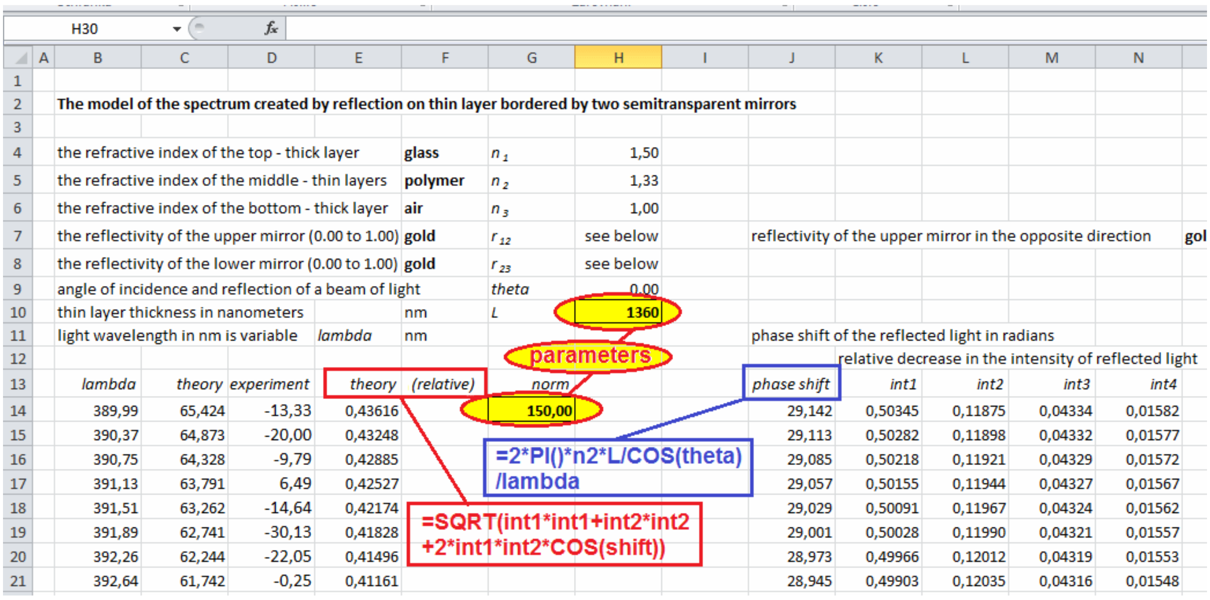

Figure 3. Basic parameters and formulae of the computational model in a spreadsheet

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The implementation of the model in a spreadsheet consists of a header, a table of values and a graph, as shown in Figure 3. The header shows the values of physical quantities that can be considered constant for all wavelengths of the incident light. Because the incident light impinges on the thin layer in perpendicular (or nearly perpendicular) direction, the indexes of refraction of all three optical layers (a thick layer of air, a thin layer of polymer, and a thick layer of glass) are considered to be constant, independent of the wavelength of light. The angle of incidence is assumed to be equal to zero.

The key parameter for the calculations is the thickness of the thin layer, L, which ranges from about 1000 nm to 1500 nm. Different values of L correspond to different specific values of pH of the environment in contact with the thin layer. Each discrete value is also assigned to an individual sheet in the workbook.

The second part of the implementation consists of a table of values in the graph. The independent variable is the wavelength of light - the respective column of the table area is labeled as *lambda*. Its values are set at irregular intervals and without rounding, because they correspond to experimentally measured values. This facilitates easy comparison of the calculated values to the real measurements.

The dependent variable is the amplitude of the intensity of the reflected monochromatic light, depending on its wavelength. There are values obtained from the measurements in the real experiments, and values obtained from the model by calculation. Theoretical values are determined as the relative intensities of the reflected light after the interference of the two reflected rays and appear in the column area labeled *theory (relative)*. In order to compare the theoretically calculated with measurements, they need to be normalized, i.e. multiplied by a suitable constant labeled *norm*, the second parameter of the calculation. Its value can be found below the cell with the label.

The resulting model is controlled by changing the key parameter L (representing the thickness of the thin layer in nanometers) and by the auxiliary parameter *norm*. By varying these two parameters, model users can achieve a good match of the two curves – one corresponding to the theoretically determined dependency of the reflected monochromatic light amplitude on its wavelength, and another one that was experimentally measured.

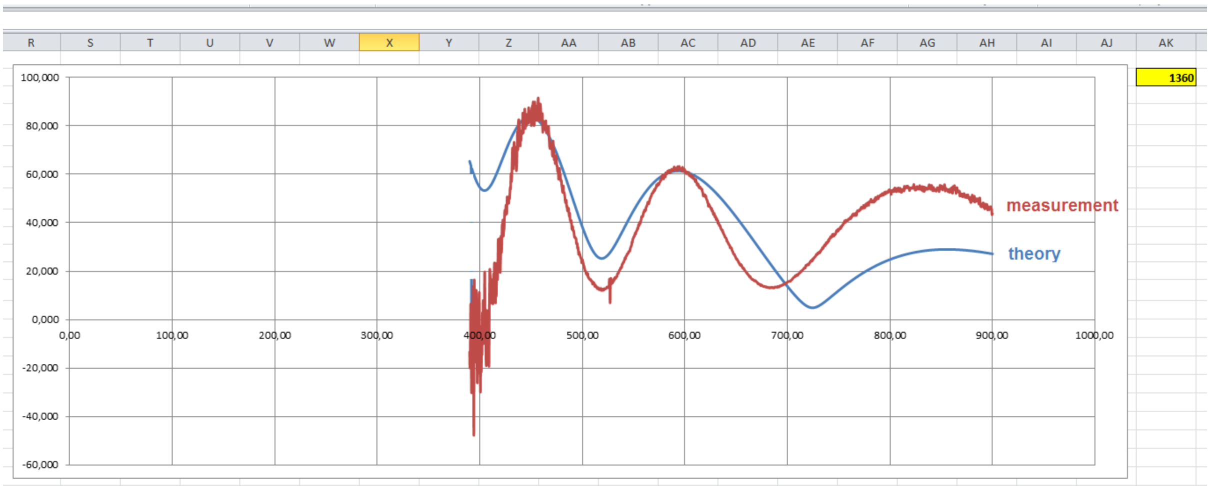

Figure 4. Graphical output of the model allows comparison of theory and measurements

4. The Use of the Model in Teaching

The model of light reflection on thin layer is first introduced to students during a lecture. They are shown the changes of the graphical output of the model following changes of the two parameter described earlier (the thickness of the thin layer and the coefficient for normalization of relative amplitudes to allow comparison against the experimental values).

Ideally, this lecture is preceded by a laboratory exercise where students measure reflection on thin layer of the polymer under ideal laboratory conditions. This requires that students have at their disposal a calibrated light source, and spectrometer capable of measuring the intensity of individual monochromatic light rays while accurately determining their wavelengths, and prepared solutions of suitable chemicals with different values of pH (suitable in the sense of not interfering with the polymer layer, only affecting the size of the

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macromolecules). The measured values should be transferred into a spreadsheet, to get ready for the next exercise using the computer model.

This second laboratory exercise is based on students' independent work with the computer model. It proceeds in three phases:

1. In the first phase, students work in pairs or small groups. Their main goal is to experiment with model parameters to find the most appropriate sensor configuration in terms of the position and intensity of the peak amplitudes of the curve describing the modeled spectrum. At this stage, students should realize that the assessment of match between theory and measurements using only the visual similarity of the two curves is very subjective, and that it is necessary to augment the model by an objective measure of the match.
2. In the second stage, students suggest, or are directed by their instructor, to use the least squares method for assessment of the match between the model and the measurements. Adding a column with squares of deviations between the theoretically calculated values and normalized measurements is a simple task suitable for independent work by the students. A measure of match is the sum of the values in this column.

3. Finally, the students adjust both parameters of the model so that the objective indicator (the sum of squares) is minimized. Parameters determined this way are then compared to the values estimated in the first stage of the computer experiment. Student then summarize both sets of values in a tabular form, verbally describe identified dependencies, and assess possible problems when deploying the thin layer device as a pH probe in the field.

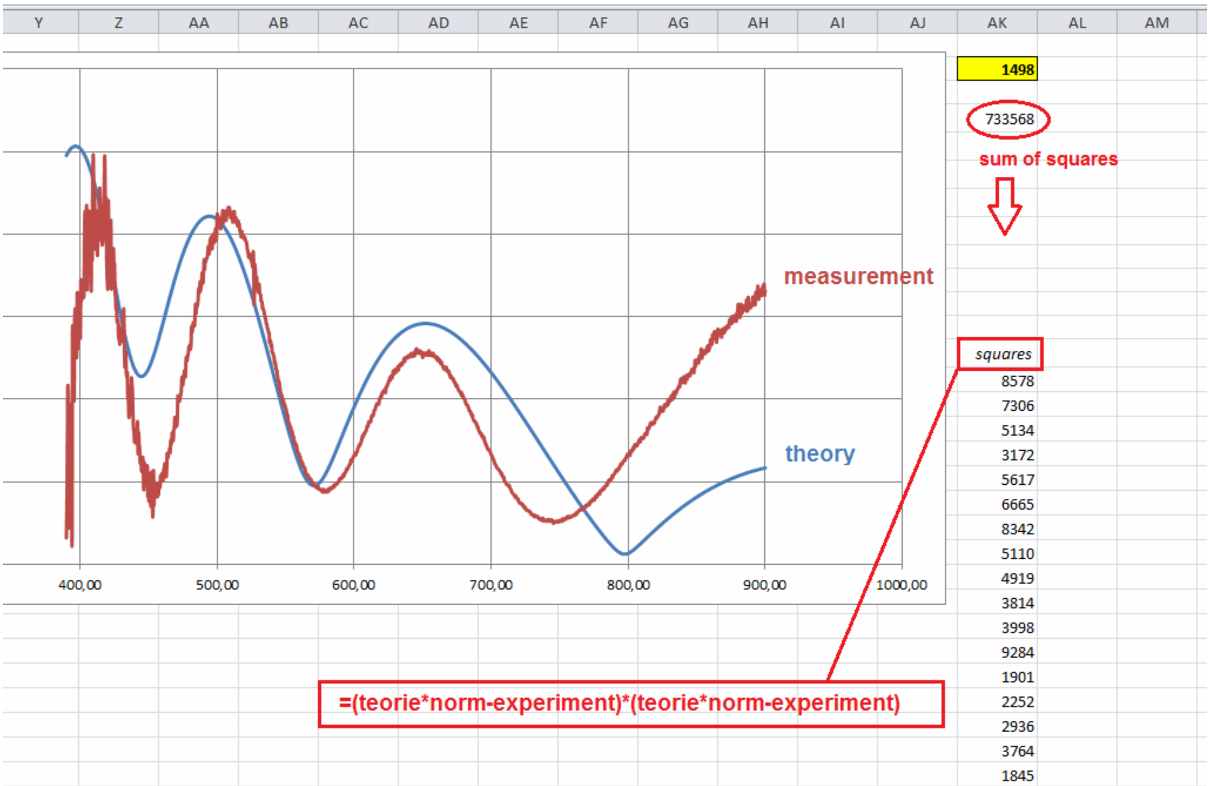

Figure 5. Model augmented by an objective evaluation of the match between theory and measurements using the method of least squares

5. Conclusions and Future Work

The described teaching process has been used only once in a small group of students. This small trial does not allow to draw any general conclusions. However, from observations and follow-up quizzes of retained knowledge, it is obvious that presentation of the classic topic from a basic course in optics in the form of practical engineering application is very motivating. The overall knowledge and the level of understanding of the subject are considerably better than in the previous years when the model has not yet been used in the classroom.

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Further research will likely continue in two independent directions. The first of these is the improvement of model accuracy. The thin layers of gold that are used as the semitransparent mirrors, likely have different reflectivity for different wavelengths. We need to find a more suitable mathematical model of these mirrors, to construct a model that better simulate the behavior of the real device.

The second direction of research is didactic. The evaluation of the motivational and explanatory potential of the model could be performed using a larger group of students focused on the field of physical and technical measurement. In such settings, the model could be objectively assessed through a properly designed pedagogical experiment. A suitable option would be, for example, to assign the students pretests and posttests to verify their understanding of the modelled optical phenomena. The students will be divided into two groups: an experimental group (which will be taught using the new model of light reflection on thin layer), and a control group (which will be taught using a lecture with follow-up solutions of traditional physical problems with fixed solutions). Results of the pretest and posttest will be compared [7] to determine normalized gain.

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How Electrical Engineering Students Understand the Accuracy Concept Concerning Digitized Signals

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Abstract

Previous studies have shown that engineering students have many difficulties understanding the concept of accuracy. A previous study exposed students' misunderstandings in Digital Electronics course. These misunderstandings are linked to digitizing of electrical signals. To overcome students' difficulties, teaching the accuracy issue in the course must be expanded. The current research investigates students' achievements after adding concepts about accuracy to the course content. Sixty-one electrical and electronics engineering students who took the course in Fall semester 2014 participated in the study. Two sets of questions concerning the concept of accuracy, applied in the context of the course, were developed and appeared in the final exam. The problems concentrated on measurement errors in digital systems, including analogue to digital converters. Both sets of problems required students to provide calculations and explanations. Their written solutions and explanations were analyzed. Examination of students' answers shows that the frequency of errors concerning accuracy found in previous studies was reduced. The analysis revealed new aspects of students' misunderstandings concerning the accuracy of digital instrument measurements. Considering the results, we suggest further improvements to the course content and continuing research to strengthen understanding of the accuracy concept.

Keywords: *Misconception, Accuracy, Error, Digitizing.*

1. Introduction

It is obvious that modern engineers must possess knowledge and technical skills in measurement science and technology. Interpreting measured values of various physical parameters and their use in engineering design is a meaningful part of engineering work. Authors of [1] note that a high proportion of engineers and scientists require expertise in the field of measurement, and there is currently a significant demand for specialists/experts. Measurement processes are always accompanied by evaluating measured results using the concept of accuracy. Therefore, measurement accuracy is an important basic engineering concept. As pointed out in [2], engineering students must acquire the conceptual knowledge, and this process is critical for the development of their professional competencies. Since understanding the concept of accuracy is extremely important for engineers, engineering education must pay appropriate attention to thorough teaching of this concept.

The International Standard defines accuracy of measurement methods and results as “the closeness of agreement between a test result and the accepted reference value”, where the latter is “the value that serves as the agreed-upon reference for comparison” [3]. In practice, the term *true value* is frequently used instead of the term *accepted reference value*. In engineering literature, there are different definitions of accuracy. Thus, [4] define accuracy as “the data on instrument error”; [5] claims that “for electrical instruments the

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accuracy is usually defined as a percentage of full scale deflection"; [6] proposes to distinguish between accuracy and inaccuracy concepts. According to reference [6], accuracy is a "positive" characteristic of the measurement, but in reality it is expressed through a dual "negative" characteristic – inaccuracy – of the measurement. The inaccuracy of a measurement is expressed as the deviation of the measurement result from the true value of the measured parameter (this deviation is called the measurement error) or as an interval that covers the true value of the measured parameter.

Learning process in engineering is often accompanied by incorrect understanding of basic science and engineering concepts. A series of studies investigating students' misunderstandings of the concept of accuracy were carried out recently. The studies show that engineering students have many difficulties understanding the concept. Thus, [7] reveals misconceptions about the concept of accuracy as expressed by engineering students taking basic electricity and electronics courses while using engineering models. In [8], it was shown that engineering students from different engineering programs demonstrated insufficient understanding of the concept of accuracy and the relationship between accuracy and error in measurement. Paper [9] exposes new aspects in students' misunderstanding of accuracy linked to digitalization of electrical signals. Students misperceived the essence of quantization of signal and noise, tended to confuse quantization and noise errors, and confused the relationships between noise and resolution.

It was with great interest that the series' authors continued their research into students' misconceptions about measurement accuracy in the area of Digital Electronics with the aim of deeper investigation of various aspects in students' erroneous thinking.

2. Research Framework

2.1. Method

As noted in [10], the conceptual understanding can be investigated by presenting students with exam problems. This qualitative method was chosen for the current research. The main research tool was a questionnaire that included two problems involving the concept of accuracy; the problems were developed and incorporated into the final exam. The written solutions and explanations were then analyzed.

2.2. Participants

Sixty-one electrical and electronics engineering students from the academic engineering college who took the Digital Electronics course in Fall semester 2014 participated in the study.

2.3. Pedagogical Background

As mentioned in [8], freshmen engineering students encounter the issue of measurement accuracy in their first physics laboratory course during their first academic year. The engineering courses that they take subsequently do not pay abundant attention to this issue. As a result, student knowledge is not refreshed, and the students have a lot of difficulties with the accuracy issue. With the aim to overcome these difficulties, teaching the concept of accuracy during the Digital Electronics course has been enhanced. Accuracy topics were added to the course content. The lecturer reminded the students of the following definitions of absolute and relative errors:

$$\begin{aligned} &Absolute\ Error = \left|A_{MEASURED} - A_{TRUE}\right| \\ &Relative\ Error = \frac{\left|A_{MEASURED} - A_{TRUE}\right|}{A_{TRUE}} \times 100\% \end{aligned} \tag{1}$$

A_{TRUE} is a true value of a measured parameter,

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$A_{MEASURED}$ is a measured value.

As shown, there are different definitions of accuracy parameters. In the course, the relative measurement error and accuracy were defined in percentage as follows:

$$Accuracy = 100\% - Relative\ Error \tag{2}$$

Accuracy topics were incorporated and solved in the lecture and tutorial example problems, and students were assigned similar problems in their homework.

2.4. Questionnaire

Two problems on the exam concentrated on error and measurement accuracy of digital systems, including sensor, Analog to Digital Converter (ADC) and display. Both were open problems and required calculations; the first problem also required students to provide explanations. The detailed questionnaire appears below.

Question 1. An engineer designed digital weigh meter included weight sensor, 8-bit ADC and display. The block diagram of the system is described in Figure 1.

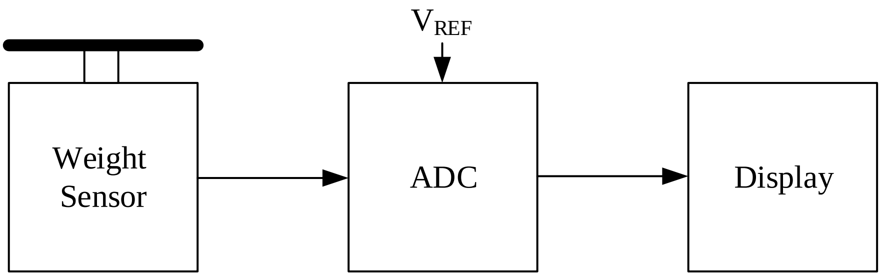

Figure 1. Block diagram of weigh meter

- The engineer chooses reference voltage V_{REF}
- The device must measure weight from 0 up to 2.55 Kg and present the value on the display
- Weight sensor includes mechanical component (spring) starting to react from minimal weight of 15 g and responds linearly for weights greater than 15 g
- Sensor characteristic presented in Figure 2.

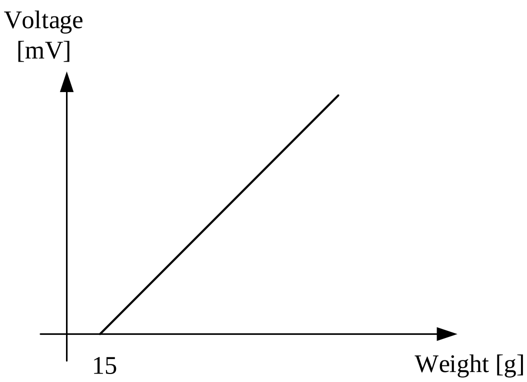

Figure 2. Weight sensor characteristic

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a. A weight of 2000 g was measured by the device. What is the relative error of the measurement? Please explain your answer.
b. A weight of 500 g was measured by the device. What happens with relative error – does it increase or decrease? Please explain your answer.

Question 2. You need to design an anemometer (wind gauge).

- The device includes a mechanical wind vane and electronic part with solar battery of 2.56V
- The device must measure wind speed from 0 to 200 Km/h
- The axis of the vane has friction which decreases rotation speed by 1%. A sensor converted rotation speed into voltage decreases the value by 0.5%.
- Conversion coefficient of the speed sensor is 1 mV/Km
- A signal from the output of the speed sensor is converted by ADC and wind speed is presented on the display as integer number
  a. What is the minimal number of bits required for ADC?
  b. What is measurement accuracy for the wind speed of 20 Km/h?
  c. What is measurement accuracy for the wind speed of 200 Km/h?

3. Results

Twenty-five of 61 participants of the study did not provide any answer to the two exam problems. Only 59% of participants tried to solve the problems using concepts of accuracy. Table 1 shows the distribution of students' answers for the problems. The table includes only the students who tried to answer the problem. It was assumed that the student solved the problem correctly if he or she acquired more than a half of the points in the problem and in total score. Only one student submitted the perfect solution of both problems and achieved the maximum total score.

Table 1. Distribution of students' answers to the questionnaire

Number of students	Q1		Q2		Total	
	Correct answers	Percentage of correct answers	Correct answers	Percentage of correct answers	Correct answers	Percentage of correct answers
36	**7**	**19.4%**	**13**	**36.1%**	**6**	**16.7%**

It can be seen that the percentages of correct answers from students to the both questions are very low. The percentage of correct answers to question 2 was higher than the percentage of correct answers to question 1. These results lead to the conclusion that the students are not yet familiar with the issue of accuracy.

Analysis of students' written solutions revealed two misunderstandings, which were not evident from the previous studies. The most common misunderstanding was that the students calculate relative error and accuracy of the measurement system on the output of the sensor instead of calculating it on the output of ADC. This error appears 15 times in the solutions to the first question and 12 times in the solutions to the second question. Thus, student S solved the first question as follows:

$$a.\;\; Error = \frac{15}{2000} = 0.75\%$$

$$b.\; Error = \frac{15}{500} = 3\%$$

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The student ignores the fact that electric signal from the output of the sensor converted by ADC into a binary number. The measurement system includes 8-bit ADC and must measure weight from 0 to 2.55 Kg. Therefore, the maximal weigh of 2.55 kg must be displayed as the number 255, and a resolution of the system is $R = \frac{2550}{2^8 - 1} = 10g/bit$. The true value (without influence of the spring) is $N_{TRUE} = \frac{2000}{R} = 200$, the true measured value is $N_{MEASURED} = \left[\frac{2000-15}{R}\right] = 198$, so the relative error is $\frac{(N_{TRUE} - N_{MEASURED}) \times 100\%}{N_{TRUE}} = 1\%$.

Another misunderstanding is expressed by the fact that some of the students (4 of 36) chose the resolution equal to 15 g/bit, meaning that the absolute error of the measurement system is equal to its resolution. Student B solved the problem this way and got the results:

$$R = 15gr;\ N_{TRUE} = \frac{2000}{R} = 133.3 \rightarrow 134;\ N_{MEASURED} = \frac{2000-15}{R} = 132.3 \rightarrow 133;$$

$$Error = \frac{134-133}{134} \times 100\% = 2.9\%$$

However, these students do not understand that the measurement instrument must be calibrated in the same way that all the measured range must be displayed on the panel. As such, they got number 134 on the display in the measure of 2000 g, while the measure of 2550 g will give the number of 170 only.

Other misunderstandings, such as confusion between accuracy and error and the claim that the measurement error of digital system always is equal to its resolution are known from previous study [9]. It must be pointed out that their appearance was lower in the current study than in the previous study (6 and 5 of 36, respectively).

4. Conclusion

The questionnaire included two questions involving the concept of accuracy. The low ratio of students who tried to solve the problems (36 out of 61) and the low ratio of correct answers (22 for the first question and 12 for the second question, of 36 respondents) likely indicates that a lot of students have difficulties with the concept of accuracy.

The current research exposes new aspects in students' misunderstanding of accuracy linked to digital measurement systems. As mentioned, the most common error was ignorance of digitizing process. The majority of the students knew the formula of relative error and accuracy, but they referred to the error of the sensor only and did not refer to the ADC. These students misperceived the essence of quantization process and quantization error of analogue to digital conversion.

Moreover, some students do not have the system perspective; they tried to decrease the system error by increasing the resolution on expense of neglecting the issue of measurement calibration, so their measurement instrument was not calibrated to display all the measured range.

Nevertheless, appearance of misunderstandings, which were known from previous studies, such as confusion between accuracy and error and confusion between error and resolution, was decreased.

It can be concluded that teaching the accuracy issue in the course of Digital Electronics improved student knowledge to some extent, but the pedagogical efforts were not sufficient. Teaching topics relating to the concept of accuracy must be more methodic, explain the theoretical foundations as well as applications in

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digital systems. The authors of the current paper intend to continue their research after the changing the course of study.

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An autonomous learning ability based laboratory course for undergraduate students studying in measurement and control subjects

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Abstract

We report a study of a specific measurement and control lab course at one university over 4 years. We found that when we taught the lab section in measurement and control subjects with a traditional course schedule, the teaching process doesn't encourage students to think actively and the students' creativity can't be inspired as we expect. To overcome this problem, we introduced an independent experimental course, which integrates the main crux of both the Basic Mechanic Engineering Control course and the Measurement Techniques of Mechanic Engineering course. In this lab course, the students are divided into small teams with three members, and they should corporate to design and develop a small mechatronic control system integrating measuring module and control module. In the whole learning process of this course, each team should complete demonstration of scheme, system design, manufacturing and assembling, system test, report writing and competition with a proper cooperation within their team. To broaden the students' horizon, experts in measurement and control will be invited to give the students several hours' lectures about measuring and control techniques in engineering practice. In addition, the lab instructor only acts as a project assistant rather than a decision-maker in the lab learning process, and his main duty is to supervise the working procedure of each team and provide some necessary guidance when some teams run into a problem. Therefore, the students can think actively, and also their autonomous learning ability can be aroused to the greatest extent.

Keywords: *Autonomous learning ability, Measurement and control, Laboratory course, Student-centered.*

1. Introduction

Along with the development of teaching reform in higher educational institutions in China, carrying out research-based teaching has become a trend of teaching reform in higher educational institutions at present [1]. In the past decades, many Chinese college graduates majoring in engineering were said to be mastering theoretical knowledge very well, while seeming to lack practical competence, and they sometimes were regarded as "High-intelligence, but low-creativity students"[2] [3]. The main cause is that the students lack enough practical training to cultivate their creativity and independent thinking habits in the college study in most of the universities in China. Therefore, to cultivate the students' creativity and practical ability, colleges and universities should transform the existing unitary teacher-centred pattern of lab teaching to new teaching models such as the bilateral student-centred teaching pattern [4],.To achieve this goal, the teachers have to make some innovations from not only their teaching styles but also the curriculums[5][6]. For the students majoring in mechanical engineering, lab training courses are necessary to promote their professional ability [7]. However, most traditional lab curriculums in the universities in China are established under the teacher-centred pattern, which don't encourage the students to think actively and learn autonomously. In the past decade, we taught two lab courses in measurement and control subjects at Huazhong University of Science and Technology (HUST), China, and found that when we taught with a traditional teacher-centred course schedule, the teaching process doesn't encourage students to think actively and the students' creativity can't be inspired as we expect. To overcome this problem, we introduced an independent experimental course, which integrates the main crux of both the Basic Mechanic Engineering Control course and the Measurement Techniques of Mechanic Engineering course in 2011 at HUST. The students in Qiming College of HUST are chosen from the freshmen every spring, and their training requirements are higher than the general undergraduates'. In the lab teaching section, we expect to cultivate their autonomous learning ability and creativity through some specific lab projects.

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In the traditional lab teaching schedules for the students majoring in mechanical engineering at HUST, we operate two independent lab courses for Engineering Testing and Signal Processing, and Control Fundamentals of Mechanical Engineering respectively. In these two lab courses, the teachers prepare the experimental scheme in advance, while the undergraduates only need to do the right things under the guidance of experiment instructions written by the teachers. As a result, what the students learn from the two courses is nothing other than passively understanding some demonstrations of measuring and control fundamentals, and it isn’t good for stimulating them to think actively and cultivating their autonomous learning ability. Besides, when we teach these two lab courses separately, the systematic concept of measuring and control is intentionally divided into two parts. Actually, the measuring and control process is so inseparable that it is necessary to introduce a lab course integrating the main crux of both the course, Mechanic Engineering Control, and the course, Measurement Techniques of Mechanic Engineering. Therefore, we adjusted the lab training programs for the students majoring in mechanical engineering at HUST in 2011. In the new lab courses schedule, other than the above-mentioned two lab courses, we introduced a new lab course, Integrated Measuring and Control Experiment (IMCE), to stimulate the students’ interests in measuring and control subjects and arouse their creativity and autonomous learning ability in measuring and control subjects. In this lab course, the students are divided into small teams with three members, the supervisor will provide some necessary experimental elements such as electric motor, temperature sensors, controller and etc., and each team can choose a lab training project from a list of measuring and control projects. Each team should corporate to design and develop a small mechatronic system integrating measuring module and control module due to their choice.

Through the IMCE lab course, we found that the students would like to think actively and cooperate with each other more smoothly when the supervisor give them a chance to fulfil a measuring and control experiment project by themselves. This lab course can enhance the students’ autonomous learning ability in mechanical engineering to a great extent, and promote their systematic knowledge of measuring and control in mechanical engineering.

2. Overview of IMCE lab course

The IMCE lab course is opened for the junior undergraduates, and its objectives include three folds. Firstly, the students can establish a systematic concept of mechatronic control system via designing and developing a whole project in measuring and control domain, and then promote their ability to comprehensively apply knowledge and techniques learned from Engineering Testing and Signal Processing, Control Fundamentals of Mechanical Engineering and other correlative curriculums. Secondly, the students can master the common tools in the mechatronic control discipline, such as Matlab, Protel and configuration software. Finally, via the training program of IMCE lab course, the students can cultivate their ability of independent thinking, arouse autonomous learning ability and creativity in engineering practice, and promote a good habit of team cooperation.

According to the syllabus of IMCE lab course, the students majoring in Mechanical Engineering are divided into small teams with three members, and each team should design and manufacture a small measuring and control system with given mechanical or electrical elements. To reach the above course objective, the student team must finish the main steps of a lab project which include demonstration of scheme, system design, manufacturing and assembling, system test, report writing and competition with a proper cooperation within their team.

Figure 1. Lecture notes with PPT for the IMCE lab course

Before the students choose the lab project they want to do, the supervisor will give 4 hours lecture (Figure.1 illustrates the lecture notes with PPT). The students can get some crucial information about the IMCE lab course and their lab projects such as the introduction of IMCE lab course, systematic concepts of measuring and control, design methods, tools, report writing techniques and how to promote an engineering project, etc. Besides, to broaden the students' horizon, experts in measurement and control will be invited to give the students 4 hours' lectures about measuring and control techniques in engineering practice.

Each student team can choose a lab project from a given project list, and then the students will design and develop the chosen mechatronic system with 12 hour Curricular time. In addition, the students can work in the machine studio no more than 8 hours on the weekend. The lab supervisor only acts as a project assistant rather than a decision-maker in the lab learning process, and his main duty is to supervise the working procedure of each team and provide some necessary guidance when some teams run into a problem.

3. Main training procedure of IMCE

In the teaching process of IMCE course, we asked the each team to design and develop a typical mechantronic control system with some given mechatronic elements (shown in Figure 2). The main procedure of the lab training section is as follows.

Figure 2. Mechatronic elements prepared for the IMCE lab training

1) The students are reorganized with small teams, each team has 3 three members, and a team must independently design and develop a specific mechatronic control device chosen from a given topic list or optional projects related to measuring and control discipline. For example, in the IMCE course opened in 2013, the given project list includes linear motion platform control, constant temperature control, constant water pressure control, Constant speed control of AC induction motor, etc.
2) After each team has chosen their project, the lab instructor or TA will give them an instruction of lab section, which includes the description of given mechanic parts or electronic elements, the rules in the lab studio, tool kits and function requirements of each specific devices. The students in each team should prepare some auxiliary elements and material by themselves.
3) Each team designs and builds the assigned mechatronic control devices following a standardized curriculum design process, which includes conceptual design, simulation analysis and demonstration, system implementation, system testing, product exhibition and oral presentation. At this stage, the lab instructor only gives the student some clues rather than the exact solutions if they run into a problem.
4) Final competition and assessment. At the end of IMCE lab course, each team should demonstrate their device to several judges, usually experts or teachers in measuring and control discipline. The judges will assess each team's work from function, control efficiency, device appearance, economy, presenting skills, and etc. Generally, we will choose two or three excellent teams after the final competition and assessment. Figure 3and Figure4 illustrate two lab projects finished in the IMCE lab course 2013.
5) The students of excellent teams were reorganized into a new team, and participated in the international collaboration project, '2013 HUST-WPI engineering practice project', which was organized by Huazhong University of Science and Technology, Worcester Polytechnic Institute, Tsinghua University, University of Notre Dame and Shanghai Jiaotong University. 'HUST-WPI engineering practice project' is an international educational collaboration project between the universities of USA and China, which was started from 2005. In this international education collaboration project, about 15 undergraduates selected from HUST will go to Worcester Polytechnic Institute every spring, and they will be organized into teams with WPI undergraduates majoring in Mechanical Engineering. These engineering practice teams will go to local manufacturing companies, and complete the assigned design projects from these companies within 8 weeks. In summer, 15 selected undergraduates from WPI and 12 selected HUST undergraduates are organized into 9 teams, and they are assigned to 3 to 4 US

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capital corporations located in Shanghai, Suzhou, Wuxi and Wuhan, China, where they must complete some engineering design projects provided by these companies. The selected undergraduates can learn a lot from HUST-WPI project such as collaboration spirit, independent thinking ability and enough practical engineering experience. In the summer 2013, 6 students were selected to participate in the HUST-WPI project because of their excellence in the IMCE lab course, and they won a prize for excellence in this practical engineering training project.

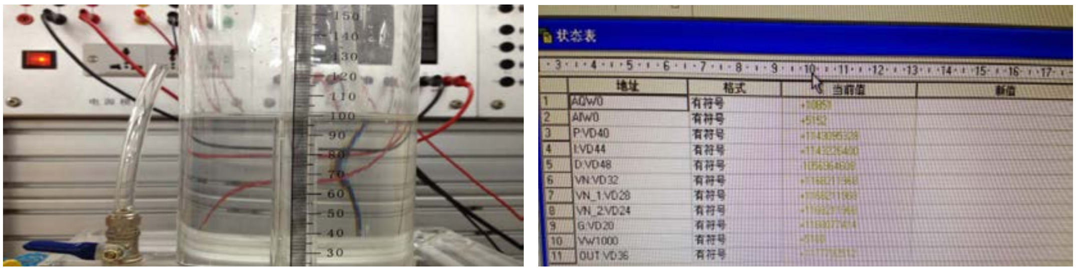

Figure 3. PLC and Simulink based constant pressure control system for a water container

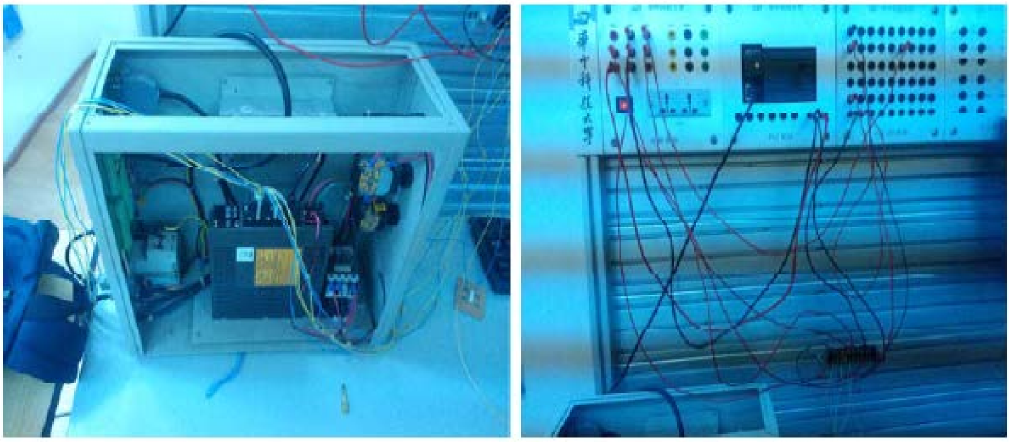

Figure 4. Simens PLC based half closed-loop control system for servomotors

4. Outcomes

4.1. Students' Outcomes

Students involved in IMCE lab course learned much more when they attended all assigned sessions. The outcomes can be outlined as

a) In the IMCE lab course, they thoroughly understood how to carry out an engineering project from problem statement to product manufacturing;
b) Get an opportunity to improve their practice competence;
c) Learn communicating skills via cooperating with other team mates especially with international team mates, and it is beneficial for their future careers;
d) Through practical hands-on works, students understood that many conditions are assumed ideally in the engineering design, while in the manufacturing process, it is not the same thing;
e) The IMCE lab course provides an opportunity to train and develop the students' autonomous learning ability. Actually, at the end of the course, most students involved in this course think more actively, and they can independently handle some thorns in fulfilling their assigned task without the lectures' interference;
f) When the students finished the project training in the IMCE lab course, they became more active and sensitive to the engineering problems. For examples, they can propose more novel design ideas at the end of the IMCE lab course than at the beginning when the instructors give them a new training project.

4.2. Professors' Outcomes

For teachers who are involved in the IMCE lab course, the can also get much in teaching.

a) Catch up with the recent trend of student-centred engineering education development;
b) Exchange teaching philosophy and methods with professors or experts from different universities or industries;

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c) Have more time to communicate with their students about some special issues. And then they can understand how their students can get more from their lectures and teaching methods;
d) Deeply understand how to shift their roles from the teacher-centred teaching pattern to the bilateral student-centred teaching pattern.
e) Continually promote their teaching philosophy and methods based on the students' feedback via the IMCE lab course.

5. Conclusion

In the IMCE lab course, autonomous learning based lab teaching methods had been introduced since it was opened in 2011 spring for the mechanical engineering students at Huazhong University of Science & Technology, China. Different from the traditional lab courses in measuring and control subjects, the teachers or lab instructors only act as project assistants rather than decision-makers in the lab learning process. As a result, the students are forced to think actively, and then learn how to solve the engineering puzzles by themselves. Of course, the students may make faults at the beginning of their projects, especially, they will do something wrong where the lectures repeatedly stressed that they shouldn't do. But the students can correct these mistakes through trying a variety of solving methods without the teachers' interference, and they won't make the same mistakes again in the following time. This result couldn't be achieved in the traditional teacher-centred lab courses in measuring and control discipline at HUST. Meanwhile, the students promote their autonomous learning ability, teamwork spirit and excellent communication ability, which are very important in their future carrier from this course. In addition, the students can deeply understand the whole solving process of an engineering project from the lab training of IMCE course, and then they can accumulate some professional experience in measuring and control discipline.

However, there exist many puzzles in the teaching practice of ICME to be resolved in the future. Firstly, to cultivate the students' autonomous learning ability in the ICME lab course, we should provide enough kinds of mechatronic components and materials, and then the students can select what they want in accordance with their own design and experiment requirements. Therefore, it's very important for the teachers to prepare these components and materials at the beginning of ICME lab course each semester. Sometimes, the teachers will face a budget problem to support this course if the students choosing ICME are too many. Secondly, for the students, the ICME course is a new curriculum combining both theory and hand-on skills to cultivate their practical ability and creativity, and thus they will ask the instructors a lot of curricular or extra- curricular questions some of which are beyond the scope of mechanical engineering. Because the experimental assignment of each team is different, at least 3 instructors or TAs are needed to meet all the students' desires for knowledge. Finally, if the assigned task for a team is more difficult than the average level, the scheduled 12 curricular hours seem too harsh for the students. To solve this problem, opening the lab studio for the students in extra-curricular time is necessary. In the ICME course 2013, we opened the working studio for additional 8 hours in the weekend to ensure that most of the student teams can fulfil their assigned tasks.

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Freshman engineering students prefer time-on-task in a Solar Energy course, rather than time-in-class!

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Abstract

Within higher education, student feedback or perceptions are useful in measuring effective instruction and are important to evaluate the nature and quality of educational interventions. Research has indicated that undergraduate engineering students really enjoy practical work scheduled in an electronic communication laboratory, thereby indicating a measure of student satisfaction. However, what do freshman engineering students enrolled for a course in Solar Energy prefer, time-on-task or time-in-class? The purpose of this paper is to present student perceptions of practical instruction offered in a Solar Energy laboratory at a university of technology. An exploratory case study is employed along with descriptive statistics of the quantitative data. An electronic response system was used in a classroom environment at the end of the course to obtain student perceptions on whether the practical instruction was enjoyable, challenging, relevant, sufficient and recommendable. A total of 84 student perceptions where gathered where 92% of the students indicated that they enjoyed the practical work done in the laboratory. 93% of the students felt that the work was relevant to the theory done in the classroom and 89% felt that more practical experiments should be done. The results of this study show that students view practical experiments in a Solar Energy laboratory as an important part of their educational development. Subsequently, it may be stated that freshman engineering students would prefer to spend more time-on-task than time-in-class where they can develop the needed skills and graduate attributes to be successful in a specific society, community or industry.

Keywords: *Theory, practice, laboratory, satisfaction.*

1. Introduction

"You don't learn to walk by following rules. You learn by doing, and by falling over." These words, by Richard Branson, do not only apply to the business world but also to the environment of higher education. A study by Freeman et al. [1] indicates that average examination scores improved by about 6% in active learning sections, and that students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning. Time-on-task can be seen as time that the student spends engaging in learning [2]. In the context of this paper, time-on-task is seen as active learning in the laboratory, where the student is actively engaged with the practical experiment. Time-in-class is seen as the time a student spends in purely theoretical classes where no practical application is demonstrated. Student feedback is necessary to determine how students feel about either time-on-task or time-in-class.

Student feedback can be seen as an important tool with regard to the improvement of the course, the quality of the course, the general student experience, the evaluation of successful techniques and methods as well as aspects which need improvement [3]. Student feedback can be used to recommend changes on a regular basis and to ensure consistent improvement of a course. [4]. Feedback can also indicate whether satisfaction has resulted from a specific course or experience, and is a well-studied topic in both the academic and non-academic world [5]. Student satisfaction indicates whether the academic institution is fulfilling their mission in providing graduates with the right attributes. Satisfied students will furthermore be more motivated to complete their studies and attend classes than a dissatisfied student [6], thereby conveying a more positive image to others and in so doing attract more potential students to a university [7]. A satisfied student will also have a better relationship with the lecturer and thus

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contribute to a better learning environment [8]. Research has shown that many undergraduate engineering students really enjoy practical work scheduled in a laboratory [9-11], thereby indicating a measure of student satisfaction. However, this was reported on only for students in an electronic communications course, with fewer results published for undergraduate engineering students in other disciplines at a university of technology. The following research questions therefore arise: What are the perceptions of undergraduate students with regard to practical work done in a Solar Energy laboratory? Do they find it enjoyable, relevant and constructive? Would they recommend it to others thereby indicating a measure of student satisfaction?

The purpose of this paper is to present student perceptions of practical instruction offered in a Solar Energy laboratory at a university of technology. This paper will firstly discuss the context of this study. The research methodology will then follow. Results in terms of bar graphs and a pie chart will then be presented along with succinct conclusions.

2. Context of the study

The Department for Electrical, Electronic and Computer Engineering forms part of the Faculty for Engineering and Information Technology at the Central University of Technology, Free State (CUT). The Department offers courses in Electrical Engineering: Light Current and Heavy Current as well as Computer Systems Engineering. These courses deal with the study and application of electricity, electronics, electrostatics and electromagnetism – which covers a range of sub-studies including power electronics, control systems, signal processing and telecommunications.

Undergraduate engineering students at CUT have the choice to enrol for a National Diploma in a number of different engineering disciplines. These National Diploma programmes often include both theoretical and practical instruction where students can demonstrate vital graduate attributes such as problem-solving and technological literacy [12]. Problem-solving requires students to use prior knowledge to find a solution to a problem [13] while a technologically literate person must have a certain amount of basic knowledge about technology [14]. These attributes may be assessed by means of practical assignments scheduled in a laboratory.

The Department implemented a Higher Certificate in Renewable Energy Technologies (HCRET) in January 2014. This is the first pre-graduate course in renewable energy that was approved by the South African Qualification Authority (SAQA). The HCRET was designed for those individuals that want to enter the renewable energy field as technicians. Successful completion of the HCRET is a way for the successful students to demonstrate that they have achieved a basic knowledge of the fundamental principles of the application, design, installation and operation of Photovoltaic (PV), Solar and Small Wind energy systems [15]. The time span for the HCRET is one year. The year is divided in two semesters, with six modules per semester as indicated in Table 1.

Table 1: Modules for HCRET [15]

Semester 1	**Semester 2**
Digital Literacy	Health and Safety: Principles and Practice
Academic Literacy and Communication Studies	Electrical Installation Practice
Mathematics I A	Power Generation and Storage
Electrical Engineering I	Solar Energy Systems II
Applied Physics of Energy Conversion	Small Wind Generation
Solar Energy Systems I	Mathematics I B

The modules termed Digital Literacy and Academic Literacy are compulsory for all the courses offered at CUT. Mathematics I A and Mathematics I B are service modules offered by the Department of Mathematical and Physical Sciences. Health and Safety: Principles and Practice is also a service module offered by a professional service provider from within this field. The practical experiments used in this paper were originally developed for the module Solar Energy Systems II. Table 2 links the practical experiments to the learning outcomes required for this module. The experiments that were done in the laboratory, and are reported on in this article, were related to the energy available from a single PV module under specific external conditions, and not to the design of a complete system (see Table 2). Five specific learning outcomes are listed which focus on the effect of different tilt angles, shading and varying light intensities on the output power of a single PV module.

Table 2: Learning outcomes that are linked to practical experiments in the module Solar Energy Systems II

Learning outcomes for Solar Energy Systems II Learners will demonstrate their competence in the understanding of:	**Practical experiments relevant to this paper that are linked to specific learning outcomes for this module:**
• The PV process • Different PV cell technologies • Energy available (PV) • PV modules • Calculating the load profile	• The effect that various tilt angles exert on the output power of a PV module [16]; • The influence of temperature on the output power of a PV module [17]; • The negative impact of shading on the output power of a PV module [18], • The I-V curve of a PV module [19]; and • The influence of different light intensities on the output power of a PV module [20].
• Sizing the PV arrays • Manufacturing of a PV cell • Stand-alone systems • Grid tie systems • Grid fall-back systems • Grid tie with backup • Charge controllers • Inverters • Batteries • Sizing the Batteries • Selecting the Inverters • Selecting the Charge control system	Not applicable to this paper as it involves a complete design

3. Practical experiments used in this module

Five practical experiments were designed and developed for this module to help students grasp the basic operating principles of PV modules. To accomplish this, the author designed and developed an innovative inexpensive practical jig, in conjunction with a computer-based program, which students personally used to change specific parameters and then observe corresponding electronic measurements. Computer-based learning facilitates consistent delivery, proof of completion and increased retention of information [21]. It exposes each student to the same practical experiment and affords each one the opportunity to provide a printout of the results, which helps to prove that the student has completed the practical experiment [10]. Other advantages to the student include self-pacing, interactivity, and data storage via USB flash disk for future reference. Furthermore, using electronic equipment within the teaching and learning environment supports the development of high-level thinking in the following two ways [22]:

- It provides students with opportunities to develop their problem-solving skills and
- It may serve as a tool for thinking and problem solving.

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The practical innovative jig comprises the following, as shown in Figure 1:

- A 10 W PV module mounted on an aluminium structure (F) where its tilt angle can be varied (E);
- A USB connector (G) from an ARDUINO microcontroller located in a watertight box with specific load resistors (D) to enable the sensed data to be viewed and recorded in LabVIEW on a PC;
- A mechanism to adjust the distance of the light source to the PV module (A);
- A switch where the two lights can be switched on or off individually (B); and
- Two 500 W halogen lights (C) which serve as the light source.

It is beyond the scope of this paper to go into a detailed discussion regarding all the practical experiments. In short, data from the different parameters of the PV module was logged and displayed via a LabVIEW interface on the computer screen. With the aid of this system, an electrical engineering student could demonstrate the achievement of the following learning outcomes:

- Document the effect that various tilt angles exert on the output power of a PV module [10];
- Assess the influence of temperature on the output power of a PV module [11];
- Verify the negative impact of shading on the output power of a PV module [12],
- Determine the I-V curve of a PV module [13]; and
- Clarify the influence of different light intensities on the output power of a PV module [14].

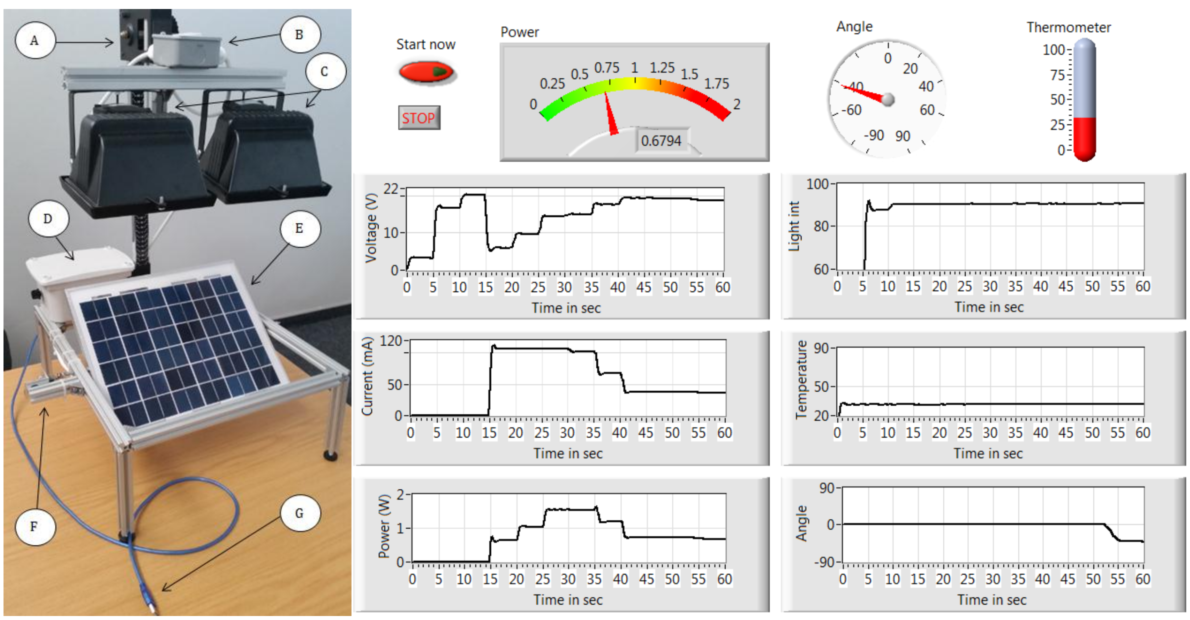

Figure 1. Experimental setup and LabVIEW interface front panel

4. Research Methodology

An exploratory case study is employed along with descriptive statistics of the quantitative data. An exploratory case study is ideal for analysing what is common and different across cases that share the same key criteria. Furthermore, it is an appropriate tool to obtain preliminary enquiries [23]. In this study, a number of practical experiments were conducted throughout the duration of the course. At the end of the course, student perspectives were obtained by means of an electronic response system with regard to all these practical experiments which share the same criteria, namely if they were enjoyable, challenging, relevant, sufficient and recommendable. Quantitative data was gathered electronically via a 5 point Likert-Scale (Strongly Agree to Strongly Disagree) and then converted into a number of bar graphs. Student perspectives can be used to evaluate teaching innovations that prompt student achievement of course learning outcomes [24]. The questions used in the electronic questionnaire were based on previous research relating to student perceptions of work done in an engineering laboratory [9, 10, 25].

5. Results

The purpose of this paper is to report on the perspectives of engineering students regarding practical experiments conducted in a Solar Energy laboratory. Student perspectives are grouped into three categories. The first category, illustrated in Figure 2, presents results relating to how students experienced the practical experiments and whether they feel they benefited from them. Figure 3 illustrates students' feelings regarding the degree of difficulty of the experiments and whether it helped them to understand the theory covered in the classroom. Figure 4 and Figure 5 illustrates possible recommendations from the students regarding the practical work.

An overwhelming majority of the students indicated that they enjoyed the practical work (92% as indicated in Figure 2 by adding the 54% (Strongly Agree) with the 38% (Agree)). In response to the question whether the practical experiments were relevant to the theory discussed in the classroom, 93% of the students agreed. A further 97% indicated that they would encourage other students to register for the module and 98% indicated that the module was a valuable learning experience. In response to the question regarding the application of new knowledge, 88% indicated that they learned how to apply new knowledge in solving engineering problems. These results tend to suggest that a measure of student satisfaction was achieved with regard to the practical work, thereby implying that they will be more motivated to complete their studies [6].

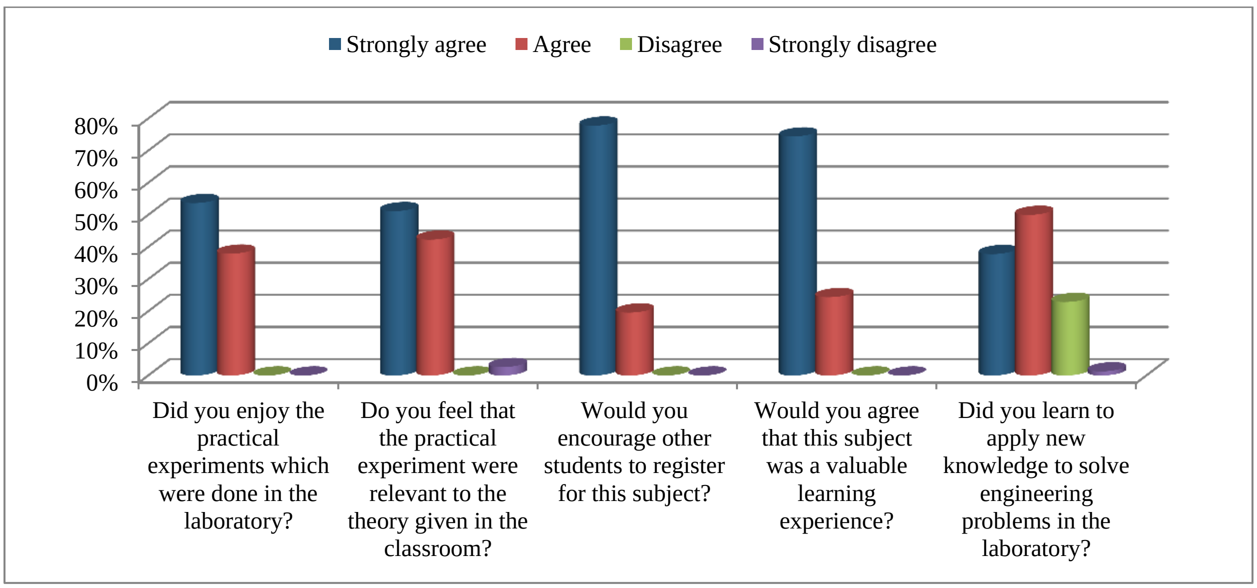

Figure 2. Student perspectives of practical work that was done in a Solar Energy laboratory

In the second category of questions (see Figure 3) regarding the degree of difficulty and whether the experiments helped the students to understand the theory, 66% of the students felt that the experiments were not too difficult. The question regarding how challenging the practical experiments were provoked a mixed reaction, as 34% of the students felt that the experiments were challenging while 31% felt that they were not challenging. In response to the questions whether the practical work helped students to better understand the theory, 76% of the students indicated that it was indeed helpful. This tends to suggest that the practical work enhanced student engagement with the course material [26], leading to a more rewarding educational experience.

The third category of questions (see Figure 4) provided students with the opportunity to make recommendations with regard to the practical work done in the Solar Energy laboratory. The results indicate that 89% of the students

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felt that more practical experiments were necessary and 86% of the students indicated that more time should be spent on practical experiments. Time-on-task helps students to make the knowledge their own and create the linkages and relationships within their own data knowledge structures [27]. The question as to whether students would prefer to work on their own in the laboratory provoked mixed reactions, as 38% indicated in the affirmative while 44% of the students reported preferring group work.

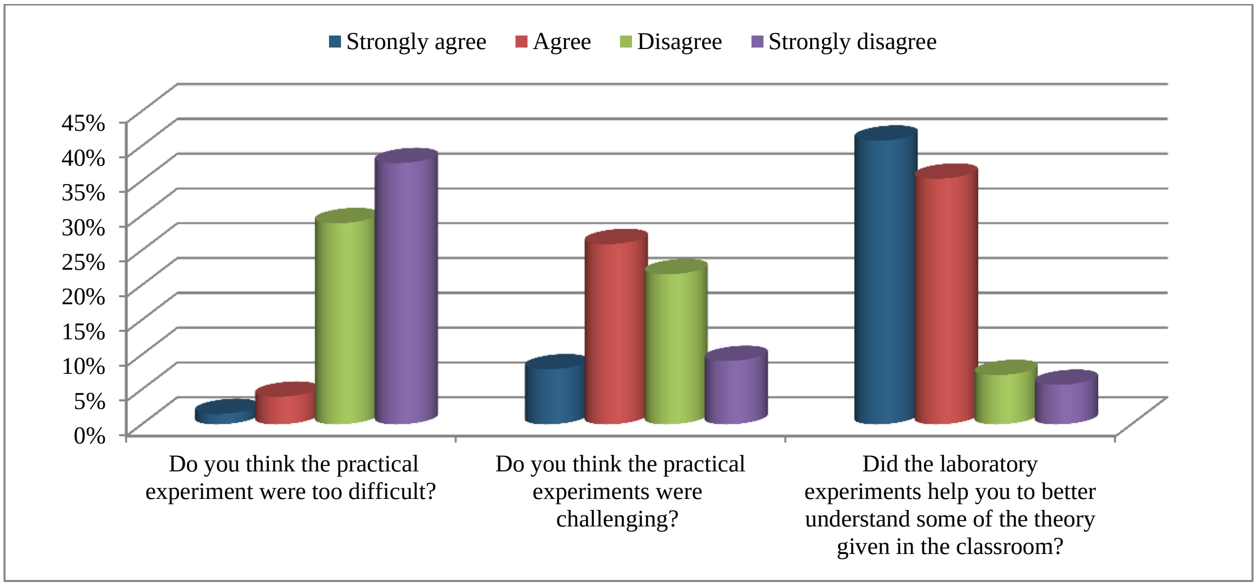

Figure 3. Student perspectives regarding difficulty of the experiments and comprehension of the theory work

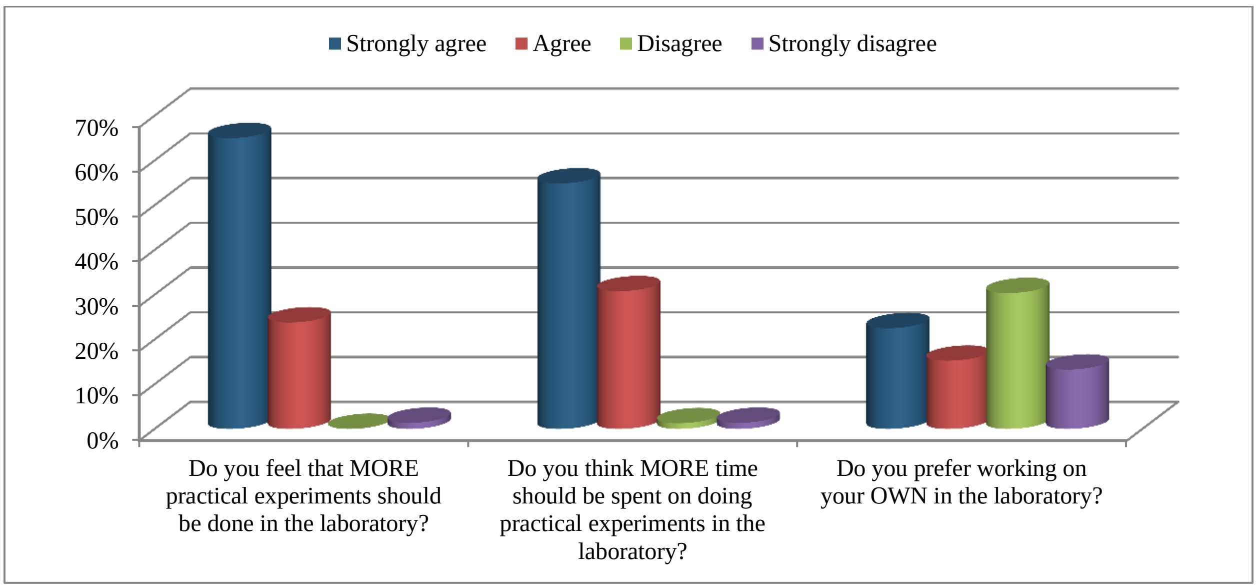

Figure 4. Student recommendations regarding practical work done in a Solar Energy laboratory

Figure 5 gives an indication of suggestions from the students with regard to the improvement of the practical experiments. Although the practical groups consisted of only 5 members each, 28% of the students felt that the groups should be smaller. Results also indicated that 8% of the students would prefer more computer-based simulations and 37% would like more access to the laboratory in the evenings. This is similar to results obtained in Australia where a survey was conducted regarding the usefulness of remotely accessible laboratories [28].

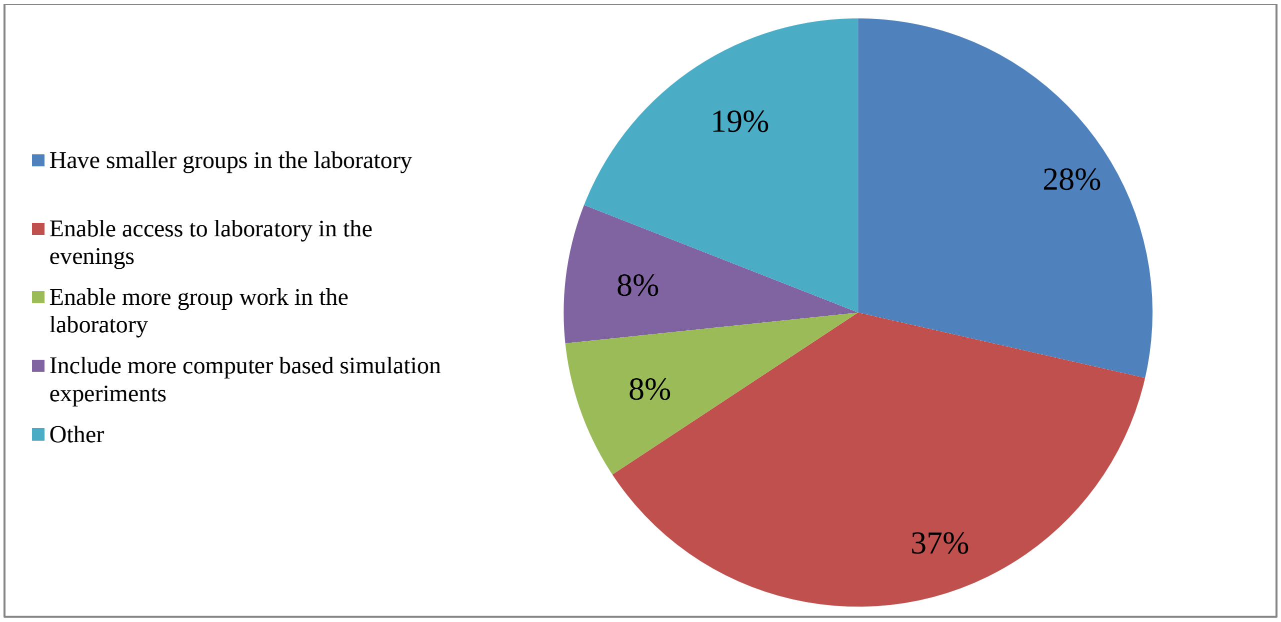

Figure 5. Additional recommendations from students regarding practical work

6. Conclusions

The purpose of this paper was to present perspectives of engineering students regarding practical experiments done in a Solar Energy laboratory. The results tend to suggest that the students really enjoyed the practical experiments, as they were a valuable learning experience helping them to better understand the theory offered in the classroom. The majority of student would encourage other students to enrol for this module as it helped them to apply new knowledge in solving engineering related problems. In response to the question of whether the experiments were challenging, 34% of the respondents agreed. This suggests that more time could be spent on explaining the experiments to the students and that more demonstrations could be done before allowing the students to try them on their own. A positive relationship seems to exist between the practical work and the theory covered in the classroom (93% agreed as shown in Figure 2). However, it would seem that 38% of the students would prefer to work on their own in the laboratory, thereby suggesting that some may want to take control of their own learning.

Although these perspectives where limited to students in a Solar Energy laboratory, they portray a similar trend as found in other engineering fields [9-11]. The importance of practical work done in an engineering laboratory cannot be overemphasised, as it provides students with the opportunity to both crystalize and apply their theoretical knowledge in solving engineering related problems. These students have indeed learned by doing and by falling over in the laboratory, rather than by only following theoretical rules, thereby demonstrating that they have acquired specific skills and graduate attributes that may help them contribute to the socio-economic development of South Africa.

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Design of a Hands-on Mechantronic Project Integrated into an Introductory course

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Abstract

It is well known that college students lack practical engineering experience. It is important to strengthen the practice of design thinking and the ability to problem solve. Hands-on experiences in engineering education are beneficial to increasing both learning and enjoyment during coursework. In order to promote student competence in innovative design, creative decision making, technical communication, and team work, a course of Introductory Mechatronics Creative Decision and Design Tool (IMCDDT) was established in 2011 at HUST, and a hands-on practice training project was integrated into IMCDDT. In the project, students are required to design a mechatronic device using the methods presented in lecture. The device competes in an end-of-semester competition. The project is important in both promoting enjoyment of competition and training students in hands-on competence. In this paper, we will describe the design of the mechantronic hands-on project integrated in IMCDDT.

Keywords: *Mechantronic Hands-on project, Mechatronics, Creative Decision, Hands-on work, International cooperation*

1. Background

The mechatronics discipline is continually evolving and becoming increasingly important in mechanical engineering. The need for mechatronics systems is being continuous driven by the increasing convergence of mechanical, electronics, and embedded software in mechantronic products design [1]. Market drivers, technological advancements, and globalization of manufacturing are leading to increase interaction between different disciplines – mechanics, electronics, embedded control software, computer control involved in different domains[2]. These effects are leading to a rising demand for mechatronics engineering studies [3]. Even though for a long time, mechatronics education has played an important role in innovation and discovery, mechatronics engineering education reforms are continually being made in engineering universities and colleges all over the world. Active practice and innovation competence are a core component of mechatronics engineering education. But, given the long existence of "emphasizing learning and despising practice" in engineering education in China, innovation practice and creative decision competence are weak among graduates. Also, because there has been a lack of a coherent and systemic approach in delivering “synergistic integration of the three components – mechanical engineering, electronics, and computer control” which is the cornerstone of “Mechatronics”, some problems with mechantronics undergraduate programs began to surface:

a) There were no dedicated mechatronics courses that integrated various mechatronics components to reinforce students’ mechatronics design skills.
b) There was a lack of sufficient mechatronics project work and laboratories. This makes the program a loose combination of mechanical engineering, and electrical and computer engineering courses, rather than a tightly focused program.
c) The mechantronic engineering graduates master the theoretical knowledge prior to hands-on experiences. As a result, they often lack the initiative practice and innovation competence required in the modern engineering environment. They have usually been regarded as "High-intelligence but low-creative students."

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These issues called for revamping the program and offering appropriate courses to improve graduates' initiative practice and innovation competence. The teaching philosophy also needed to be transfered from a focus on only teaching theoretical knowledge and design in class session to a focus that includes training practical competence (hands-on work), team work, and technical communication. This change in focus naturally leads to a project-based teaching model. However new courses must be developed to support the project-based teaching model.

In order to promote student competence in innovation design, practice, creative decision, communication, and team work, a course of Introductory Mechatronics Creative Decision and Design Tools (IMCDDT) was developed in 2011 [4-6]. The course is conducted by professors from the Huazhong University of Science and Technology (HUST) , the Georgia Institute of Technology (GATECH) and Arizona State University (ASU) in the United States. In IMCDDT, a mechatronic design competition is completed by students. This project creates both interesting and relevant hands-on experiences for a wide range of topics including design processes, basic mechatronic concepts, technical communication, and working in a team environment.

In this paper, the design of a hands-on project integrated in IMCDDT is described. Section 2 introduces the course. Section 3 introduces the mechantronics hands-on project. Section 4 describes the outcomes of IMCDDT. And in section 5 we conclude the project.

2. Introductory to IMCDDT

The IMCDDT course is set up for sophomores who have almost no experience with engineering, not to mention mechatronics concepts. Based on the philosophy of project-based learning, this course is designed to provide students with both interesting and relevant hands-on experiences for a wide range of topics, including design processes, basic mechatronics concepts, technical communication, and working in a team environment.

2.1. The goal of IMCDDT

The goals of IMCDDT are focused on:

a) Build an engineering education platform for learning mechatronics, creative decision making, and design tools.
b) Improve competence in innovation practice and creative thinking.
c) Provide practical experience in hands-on building, design, and team work.
d) Develop an engineering educational philosophy of solving problems via team work, do-it-yourself activities, and learning by doing.
e) Build a new engineering education model by focusing on both practical training and theoretical teaching, project driven, hands-on production, and competition-based evaluation.
f) Cultivate students' practical ability, innovative thinking ability, decision-making ability, design ability, team work spirit, and competitive spirit.
g) Encourage faculty to keep pace with well-known universities throught the world in both teaching ideology and teaching methodology.
h) Build a teaching group that comprises faculty from both HUST and international partners such as Georgia Tech and ASU. The group will become a model for innovative teaching and education reform of engineering education in the mechanical school of HUST.

2.2. The contents of IMCDDT

There are two main components of IMCDDT. One is the integrated competition project designed for hands-on work and the other is theoretical knowledge. The integrated hands-on project will be presented in Section 3. The theoretical knowledge structure and lecture layout of IMCDDT is shown in Figure 1.

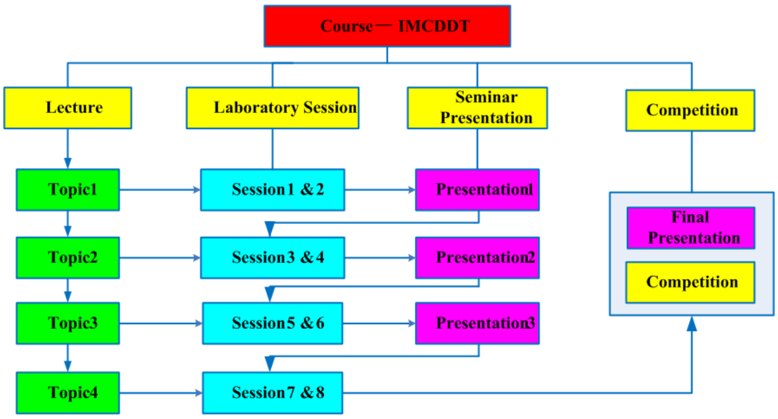

Figure 1. The theoretical knowledge structure and lecture layout.

It is always challenging to introduce mechatronics concepts to the students when they barely understand the basics of engineering from their 2nd year courses. They certainly have limited knowledge about engineering mechanics and electronics. Because of this fact, IMCDDT's contents defers from those course of senior years and even postgraduates. Because IMCDDT is designed as an introductory mechatronics course, IMCDDT does not emphasize "how" to design a mechatronics product for a customer; rather, the course introduces only the most basic concepts on "what" a mechatronics product is, as well as "what" kinds of tools can be used to design a mechatronics product. The justification for this consideration is that the students in this course are sophomores with no practical engineering experience. We primarily hope them to understand what a mechatronics product is, what kinds of mechanical/electrical components can be used to construct a mechatronics product, and what kinds of tools can be used to help design a mechatronics product. What theoretical knowledge they should learn in the following years is necessary for designing and manufacturing a mechatronics product. So the teaching of theoretical knowledge, as well as design tools is divided into four parts:

a) Tools for problem understanding

Tools for problem understanding include tools for understanding customer needs and product functional decomposition tools. In this part, students learn what tools can be used to understand customer requirements at the beginning of a mechatronics project and what tools can be helpful for transforming the requirements into product functions. In this part of the course, several tools are introduced to students: Problem Understanding Form, House of Quality, Function Tree, Function Block Diagram, and Specification Sheets. These tools help students work effectively during the first stage of mechatronics design.

b) Tools for conceptual design

Conceptual Design usually means concept generation, and safety considerations. In this part of the course, students learn to use tools such as the Solution Function Tables, Morphological Charts, Concept Evaluation Matrixes, and Safety Consideration Guidelines. After learning this material, students extend their knowledge to design a mechatronic prototype that will fulfill customers' needs.

c) Tools for project planning

The project planning tools taught in this part of the course are Planning Tree Diagram, Gantt Chart, Prioritization Matrix, Job Responsibility Matrix, and Peer Review Forms. In this part of the course students learn how to use these tools to plan, execute, and monitor their projects.

d) Tools for technical communication

In this part of the course, students learn to communicate effectively with their team members, managers, and customers. Methods for preparing images, writing reports, documenting sources, and editing technical presentations are taught to the students. Also, several communication tools via internet such as email, skype, QQ, and WeChat are reviewed for use as technical communication tools.

3. Design of Mechantronics Hands-on Project

It is believed that the earlier the students are exposed to practical mechatronics training, the more effective they are mechatronics design at the later stages. However, the students involved in IMCDDT program are just learning about mechanisms, electronics, and software coding; and it is too soon to utilize them in a project. Hence, the hands-on project has to be carefully designed so that the hands-on training achieves the objectives of reinforcing students' mechatronics thinking and that the students are able to absorb the knowledge.

As the first mechantronics course within HUST, IMCDDT serves as a foundation for the following two professional education years in mechatronics engineering. It covers important topics and tools of mechatronics system design and understanding (tools for problem understanding, tools for conceptual design, tools for project planning and tools for technical communication). These topics include mechatronics design approach,

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mechatronics components (actuators, sensors, signal conditioning), mechanical design, electrical design, electrical circuit theorems, introduction to control, and introduction to project management.

Emphasis is placed on “Learning by Doing” through an integrated hands-on mechatronics laboratory project.

3.1. The goals of Mechantronic Hands-on Project

A unique aspect of the IMCDDT course is that an integrated mechatronics design project is carefully designed into the course. The objective of this project is to create both interesting and relevant hands-on experiences, as well as for a wide range of topics including design processes, basic mechatronics concepts, technical communication, and working in a team environment. The specially-designed laboratory hands-on project puts emphasis on the students’ problem-solving and hands-on abilities. This provokes the students to think “mechatronically”; and to link component technologies to integrated mechatronics systems, and theories to applications.

3.2. Description of Project

The mechatronics hands-on project is used to achieve most of the course goals. Every student is on a team of 2 or 3 students. There is no leader in the team. Every member in a team possesses his/her own sub-tasks, and also he/she should collaborate with other members to integrate his/her task with the overall project tasks.

The theme of the competition is designed and inspired from a social event in the year of the course lectured. In 2012, the topic was rescuing victims from a flood, because in that year many places in China suffered flooding. In 2013 a huge earthquake appeared in Sichuan, China, so the topic was rescuing victims from an earthquake. Last year Change- the first Lunar Rover was popular in China, so we designed a contest based on exploring moon.

To create a fair and interesting competition, while introducing the students to design in the face of conflicting requirements, a number of design constraints are placed upon the student devices. For example, except for the actuators provided in the supply kit, each team may buy no more than one actuator and spend no more than $25 to buy construction materials. Each team's device must have dimensions smaller than 600x400x600mm (length x width x height). Students must also consider the aesthetics of their device because they will be evaluated by judges.

Typically, the functions of the student machines include:

a) Moving the machine forward/backward and left/right;
b) Picking up and laying down objects;
c) Sensing objects;
d) Depositing items at target locations;
e) No more than two other movements defined by students themselves based on their designs.

The design project is assigned to students at the begin of the course. At the same time, the students are randomly assigned to different teams. Information required to complete the project is disseminated during lectures. In the eight-week project period, students are required to design the mechatronic device using the methods presented in lectures. They also must construct the devices using the supply kit and facilities that are provided. Because it is a first building experience for many students, the construction task is a big challenge for them.

In addition, the students are required to document the process of the design and construction and to present design reviews to the class. Three presentations are given by each team during the project using this schedule:

a) The first one is at the start of the second week. Each team introduces their draft design plan and gets suggestions from faculty and other teams;
b) The second presentation is at the end of the third week. At this time each team shows their refined design plan and introduces their plan for constructing the machine. As before, faculty and other students give some suggestions to them;
c) The last presentation is before the final contest. In this presentation, each team introduces their outcomes of the course lectures and their hands-on design project.

After a student team finishes the design and construction of a mechatronic device, they are entered into an end-of-semester competition. Prior to the competition, student machines are shown and judged in a science fair based on aesthetics, ingenuity, and the quality of the presentation of their devices. During the contest, two students’ machines work together to complete a task in a limited time period. The two machines are collaborators and competitors. One machine can not disturb another one's work. After the contest, each machine gets its own points according to the amount of work it performed. There are two opportunities for every student team participating in the contest.

The project topic varies every year in order to keep the contest fun, interesting, and current. But the basic functions that the student machines must perform remain constant. The reasons for this are: (1) the supply kit and tools that are provided to the students can be used for many terms, saving money; (2) ease of formulating the project; (3) facilitate the organization of the final contest.

3.3. Components Provided in Project

A supply kit with basic components necessary for students to construct their machine is provided. Various electro-mechanical and pneumatic components, as well as a stand-alone controller with remote operational box are included in the supply kit, as shown in Figure 3. In addition, aluminum extruded sections and some kind of conectors and wires are available for use so students can focus the design of their machine on mechatronics aspects, not on what material to choose.

We also provide some machine tools and various hand and electric tools in studio for students' to use. Students can use these tools to construct their machines under faculty supervision. Figure 4 shows the construction tools.

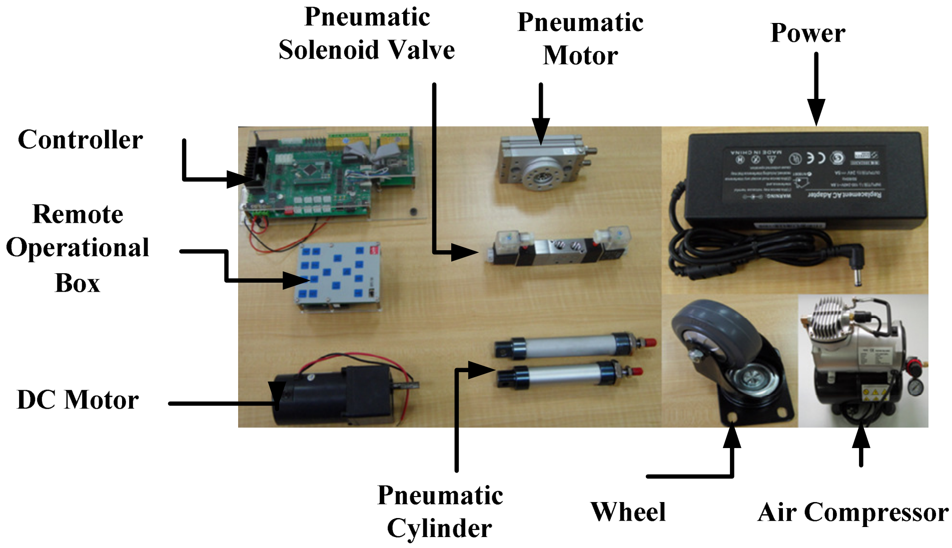

Figure 3. The components in the supply kit

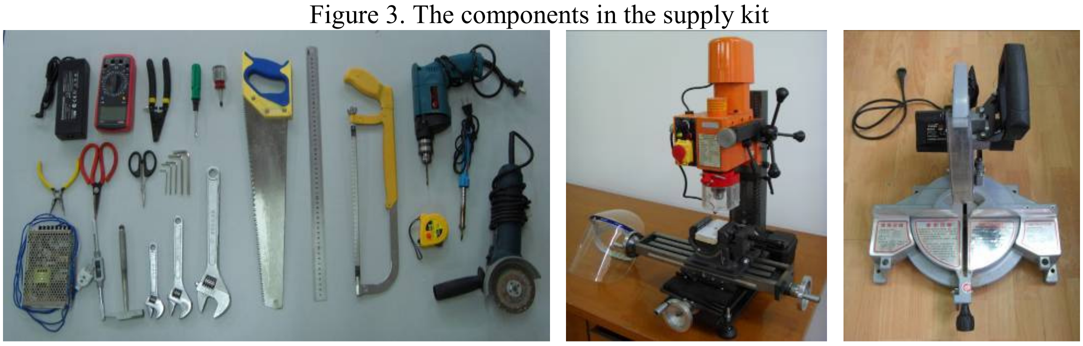

Figure 4. The machine tool and hand/electric tools

4. Outcomes

4.1. Students' Outcomes

Students who are involved in the IMCDDT course learn much more when they attend all course sessions. The outcomes can be outlined as:

a) Early in their university experience they learn mechantonics thinking;
b) Students get a chance to improve their practice competence;
c) They learn cooperation skills via working with other team mates especially with international team mates, this is esscential to their future professional success;
d) They experience foreign culture via work with international students and attend international professor's lectures;

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e) Through practice hands-on works, students learn that during engineering design many conditions are assumed ideal, but in the manufacturing process, conditions always deviate for the theoretical.
f) The course provides a opportunity for students to understand better their future engineering education.

4.2. Professors' Outcomes

For teachers who are involved in the IMCDDT, there are many positive outcomes:
a) They keep pace with current engineering education methods.
b) They exchange teaching philosophy and methods with professors from foreign universities, and learn American teaching philosophy.
c) They have more time to communicate with their students. That is important for teachers to understand their students outcomes about their lectures and teaching methods.
d) They continually improve their teaching philosophy and methods based on students feedback.

5. Conclusion

The mechatronics course setup in HUST in 2011 is beneficial for students learning both mechtronics thinking and practical hands-on competence. Also, students involved in IMCDDT leaned how to communicate and cooperate with their team members, which is essential for their future professional job. Students experience the different countries' culture via attending lecture sessions and studio sessions. Meanwhile, teachers involved in IMCDDT keep pace with international engineering education philosophy.

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Making "Physical Chemistry" a more interactive and cooperative experience

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Abstract

This contribution reports on a systematic effort to exploit hidden resources in an "Advanced Physical Chemistry" course in order to make them available for students needing more help than on average. The module is placed on M.Sc. level in an international programme and thus contains students with quite diverse cultural and language backgrounds, as well as diverse specific skills from prior studies. Several instruments like cooperative exercise platforms, bonus systems at examination time, inclusion of students in the selection process for the module contents, or the use of interactive graphical software have been tested in a coordinated way over three years to assess the influence on learning behaviour and cooperativity among the students. The project was embedded into and funded by a broader initiative on university level addressing continuous change and improvement in teaching methods. New ideas in the field of engineering education like bonus systems, supporting key competencies and collaborative learning settings play a significant role in this programme.

Keywords: *key competencies, bonus systems, collaborative learning, Physical Chemistry*

1. Introduction

1.1. Background

The Bologna Declaration of June 1999 triggered a series of reforms needed to make European Higher Education more compatible and comparable, more competitive and more attractive for Europeans and for students and scholars from other continents [1]. Accordingly, European Higher Education systems are undergoing radical restructuring in line with objectives defined by the Bologna Process. The three overarching objectives of the Bologna process have been from the start: introduction of the three cycle system (bachelor/master/doctorate), quality assurance and recognition of qualifications and periods of study. Key competencies are not explicitly mentioned in the official documents on the Bologna process but key competencies are closely related to an explicit objective of the reform efforts: enhancing employability of higher education graduates [2].

Driven by the Bologna reform a lot of deficits within study programmes and especially in the practice of higher education became obvious. Accordingly, many reform programmes in Europe have been started to enhance the quality of higher education (e.g. by the Federal Government of Germany in 2011 or within the European Lifelong Learning Program LLP). A very important objective of a lot of these programmes is fostering engineering education. “The task of higher education is to educate students to become effective modern engineers – able to participate and eventually to lead in aspects of conceiving, designing, implementing, and operating systems, products, processes and projects. To do this, students must be technically expert, socially responsible, and inclined to innovate.” [3]

To enhance the quality of engineering education is one of the most important goals of the project “Change affects” of the Münster University of Applied Sciences (MUAS). MUAS is taking part in the nationwide quality programme of the Federal Government of Germany, called “Qualitätspakt Lehre” with a budget of

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9 Million Euros for our university between 2011 and 2016. The project "Change affects" stimulates an ongoing process of change of teaching and learning along the guiding principle of the shift from teaching to learning [4].

Three key actions are established within this programme: a) A competition of the best ideas: The entire staff of the university has the chance to submit a proposal of ideas how to improve the quality of teaching and learning in their environment. A board of experts in the field of academic instruction select the best ideas and fund the project ideas up to 120,000 €. b) A consulting team of scientific experts initiate, accompany these selected projects and evaluate them. This team of experts is the coordinator of the programme "Change affects" and is organized as a service centre for quality management ("Wandelwerk"). c) An in-house further education programme provides a lot of short impulse seminars and workshops and supports the change process.

One of the selected ideas within the competitions 2012 and 2013 was the project "Advanced Physical Chemistry". This project combines a lot of requirements of competence based learning: current engineering education should encompass a set of learning experiences that allow students to construct deep conceptual knowledge, to develop the ability to apply key technical and professional skills fluently, and to collaborate within the learning process [5].

Engineering curricula and teaching methods are often not well aligned with these goals. Curriculum-level instructional design processes should be used to design and implement changes that will improve alignment. "Advanced Physical Chemistry" shows an alignment between the methods used in the classroom and assessed in the exam of the module. The project encourages students to improve their key competencies in the field of information literacy and to find alternative accesses to expert knowledge. "Advanced Physical Chemistry" is designed as a continuous improvement process, definitely not limited to the achievements of the present project.

1.2. Starting point for the project

Throughout all types of higher education, study programmes in "Chemistry" or "Chemical Engineering" contain compulsory modules concerned with Physical Chemistry on various levels. For the average student, this is often a difficult matter: the subject is by its nature much more abstract than the rest of chemistry, and the application of some moderately advanced mathematical tools is necessary. However, there is always a minority of students being very much interested in the subject, bringing in skills useful in the module, but not present with the rest of the group. In standard teaching settings (lectures, prepared exercises, labs) it is often depressively difficult to employ these skills for the progress of the whole group.

The course selected for this project (Advanced Physical Chemistry) is a compulsory module in the consecutive M.Sc. programme "Chemical Engineering", which is taught in English and open for international students, both from within the European Union and beyond. As a consequence, about 30% of the participants have not acquired their B.Sc. grade at MUAS and thus are forming a very heterogeneous learning group, both in terms of chemical, language and learning skills. The module requires a calculated workload of 240 hrs per semester; however during evaluation exercises it turned out, that most students spent considerably less time on the course; from a survey conducted at examination time it appeared, that not more than 140 hrs were invested on average. Therefore it was clear that there was much room available for more intensive cooperation, without increasing the workload for the students in an unreasonable manner. More time spent on exercises, discussions and problem solving should also enhance the long-term learning success, since this seems to be correlated with the depth by which problems have been analyzed and worked on [6].

Cooperative learning formats started to become interesting when the internet became available globally. A first surge of distributed formats ("massive open online courses" or MOOCs) seemed to have the potential to wipe out the classical localized lecture for a closed group of students, but meanwhile much of the initial excitement has been lost, since only a very small fraction of participants in MOOCs manages to complete the courses and pass examination [7]. More recent developments therefore are rather concentrating on blending online-experience with classroom-based formats, thereby also taking into account the diverse learning cultures found in different countries [8]. Most obviously, formats without face-to-face contact and group-based learning experience are useful for strong students only, but fail to help those in need of more detailed instruction and advice.

2. Methodology

2.1. Preparational phase

Using the M.Sc. module "Advanced Physical Chemistry" as a platform, it was tested first in a forerunner project, to which extent students are prepared to share knowledge and skills within the class, interact in cooperative learning settings, and get engaged in peer assessment. At this point it was also checked to which extent the students in the group had experience with graphical software, symbolic mathematics, advanced text processing and scientific software in general. In this preparational phase, standard evaluation methods (paper-based questionnaires) and static shared documents (edited and updated solely by the instructor, but distributed over the intranet) were used, albeit the members of the group could suggest changes continuously to the instructor. Since the course is a compulsory one with a relatively high number of credits, no disruptive changes could be made, in order to guarantee sufficient continuity and predictability to participants, also in view of examination and graduation. Insight from this phase with a first group of students was then used in the following years in a second and a third group of students. The size and the background of the groups was similar in all years, since "Advanced Physical Chemistry" is compulsory in the programme for Chemical Engineers, so in total the results described below have been collected from developments and experience made over ca. three years.

2.2. Introducing and setting up a cooperative learning environment

After completing the preparational phase, the first project step (with a new group of students) was to replace static shared documents by internet-based documents, open to be edited by all members of the class. Changes now could be made during the class as well as at any other time. In order to secure the necessary privacy, access was protected by a password communicated to class members only. Separate documents were prepared for various threads: questions and answers with respect to the lecture part, discussion of exercises, sharing of additional material and resources, preparation of seminar contributions etc. The software solution used for this approach was so-called "etherpads" hosted at the Mozilla foundation (etherpad.mozilla.org).

There are several reasons in favour of this specific software solution: the whole system is completely browser-based and does not need any local software installation. It is therefore completely independent of operating systems and does not require registration by the (student) users. Only for organisation and administration (setting passwords, creating and deleting etherpads etc.) the instructor has to register and set up a domain for the etherpads at the hosting organization. Contributors to the documents can either choose to stay anonymous or identify themselves by a colour code. This is in stark contrast to systems like google+, which do allow to form discussion groups, but require every participant to register and thus do not protect the privacy of the participants well. Internet bandwidth and computing power needed are very small, so the etherpad approach does not need sophisticated infrastructure and thus keeps technical barriers as low as possible. The documents themselves are text-based, therefore copying and pasting from and to other applications is simple and straightforward. The contents is saved continuously with the host system, and due to the function of a "time slider" (restoring previous contents of the etherpads over the whole history), no contribution or change can get lost. Moreover, it is an open-source-solution (http://etherpad.org/) and therefore does not require (costly) software licenses and may even be compiled and hosted at a local institution, if preferred.

In order to make the results of debates and solutions of exercises on the etherpads meaningful and permanently useful for the students (e.g. for preparation for exams), a hard-copy of the corrected contents was prepared by the instructor after completing every thread. A continuously growing document with these "approved" results was then made available as a pdf-image on the homepage of the module.

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A major disadvantage of the etherpad system is, that graphical elements can not be integrated seamlessly, due to the text-only nature, and have to be stored in separate repositories. Script-based systems like gnuplot (www.gnuplot.info) or LaTeX (www.dante.de) however can be worked on in etherpads as well, at least in order to exchange tricks and find bugs. In order to lower the barrier and give an example to start with, a gnuplot-script was made available on the homepage of the module, set up to help with data analysis of one of the lab exercises. In a similar approach, a separate etherpad was dedicated to the exchange of LaTeX scripts and tips. Students were encouraged to use these scripts as starters and modify them at will.

A large part of the course in “Advanced Physical Chemistry” is dedicated to molecular modelling. Suited high level software for exercises and problems can be found in the open software domain as academic freeware or open source software, but also on a commercial basis. For the purpose of this course and project, the GAMESS suite (www.msg.ameslab.gov/gamess/index.html) as computational engine combined with MOLDEN (www.cmbi.ru.nl/molden) as the graphical interface for model building and result interpretation were selected; both are free for academic use and can be installed by students also on their own computers. Moreover, they are working via text-based command files, so it is possible to exchange related stuff via the etherpads generated for the course. Nevertheless, these programmes have also been installed on a small set of computers in the department to make them available to students who are lacking experience with software compilation and installation. For those preferring a completely integrated molecular modelling software (combined graphics and computational engine), ready to run out of the box on simple Windows computers, there are also some solutions available (e.g. ArgusLab, freeware for individual and academic use, see www.arguslab.com/arguslab.com/ArgusLab.html), but with restricted functionality. Also here, result files and input files are text-based, so exchange and discussion via etherpads is simple and straightforward.

2.3. Organizing incentives and feedback

Finally, an element of peer review was introduced (again with a new group, based on previous experience), in order to establish a bonus system rewarding contributions to discussions and questions as well as to seminars. Although such an approach has been tested quantitatively in larger groups [9], it was used in this project on a minor scale only, in order to probe the willingness of students to take part in self-assessment. To this end, every student was given 10 bonus points (based on a written exam with 100 achievable points), that could be distributed to others, en bloque or in portions. These points were taken into account in the final exam on top of the points earned in the written part, so this was actually serving as an overall bonus for the whole group.

Another element of self-organization was introduced with the third group of students in this project by reserving some time at the end of the course (2 to 3 weeks out of 14, depending on demand) for contents suggested by the participants. It was left open to the students to decide, whether this time should be used for a more in-depth study or review of the material already presented, or whether additional subjects or application-related issues should be covered. Finding this contents was organized again with the help of a dedicated etherpad, non-moderated by the instructor, but with a set deadline in order to give the instructor some time ahead to prepare additional material, if necessary.

Shortly before completion of the coursework for the second and the third group of this project, paper-based evaluation questionnaires were distributed which addressed explicitly the new elements tested. The results were discussed with the students at the end of the course, especially in view of individual experience, and whether the additional workload caused by the new elements was justified. In parallel, the instructor checked on the basis of examination results, whether the average grade acquired showed substantial changes.

3. Results and Discussion

One of the overall results of the project is, that students especially in the engineering and physical sciences seem to feel a high barrier against cooperative types of teaching and learning. Only with the help of a bonus systems for examination, this behavioural pattern could be broken up. In the following, some observations and some progress in this respect will be listed and discussed.

3.1. Competencies and Capabilities

In the beginning of the project it turned out, that the majority of students did have only very limited experience with advanced graphical and mathematical software; internet browsers, e-mail clients and an office package were the only software pieces known to many, although almost everybody was using social platforms for communication and data exchange. Collaborative learning was realized only in the framework of self-organized small workgroups; sharing of tools took place within such groups exclusively.

As an illustration, Figure 1 shows the (static) document for the compilation of shared resources, after ca. 75% of the semester was spent with the first group (28 participants) in the preparational phase of the project (edited and updated in several categories by the instructor, in response to contributions by students, and distributed on the course homepage). The colour code identifies contributors (anonymized here, but open for course members via password-protected access) in order to facilitate exchange and discussion. Only three codes are present, with one (black) being the instructor, placing some entries as a teaser. Apart from this, the document is essentially empty with respect to contributions from group members. With such a static document, it was also difficult to find out, to what extent the shared resources have been used actually by other group members. This observation clearly shows, how high the barrier is for exchange and collaboration, whereas the reasons for this are far from being obvious.

Shared Resources — Advanced Physical Chemistry

	Molecular Modeling	Statistical Thermodynamics	General Chemistry	Equilibria / Thermodynamics	Graphics	Mathematics
Books	David S. Sholl, Janice A. Steckel: Density Functional Theory: a practical introduction (Wiley, 2009)					
Articles	C. Sheng, W. Zhang: Fragment Informatics and Computational Fragment-Based Drug Design: An Overview and Update, doi 10.1002/med.21255					
Software	www.arguslab.com/arguslab.com/ArgusLab.html www.cmbi.ru.nl/molden www.msg.ameslab.gov/gamess/index.html				www.gnuplot.info inkscape.org	
Net			www.chemgapedia.de ocw.mit.edu/courses/#chemistry	webbook.nist.gov/chemistry		www.wolframalpha.com
Blogs and groups						www.dante.de

Contributed by XXXXXX XXXXX / XXXXXX XXXXXX / XXXXXX XXXXXX

Figure 1. Document with shared resources after 75% of the semester spent with the first group

After the introduction of etherpads in the second group (34 participants), editable by class members without interaction with the instructor, significantly more group interaction and discussion was triggered, especially on the etherpad reserved for the discussion of problems and exercises, as well as on the one dedicated to "questions and answers" with respect to the contents of the lecture part. Fig.2 shows a screenshot about such a discussion; the contributions are color-coded according to the contributor (author key has been greyed out in this example in order to protect the privacy of participants). From these codes, the number of active participants relative to the size of the group could be measured on each stage of the course. Underused pads (e.g. the one concerned with LaTeX tips) were removed after a while, in order not to distract the students too much. However, in almost all cases, the number of active contributors in these discussions was quite small, therefore they were always dominated by an active minority. However, discussions in the class showed, that the contents was regularly followed by most members of the class, so it can be expected, that the discussions were valuable for the more silent participants as well.

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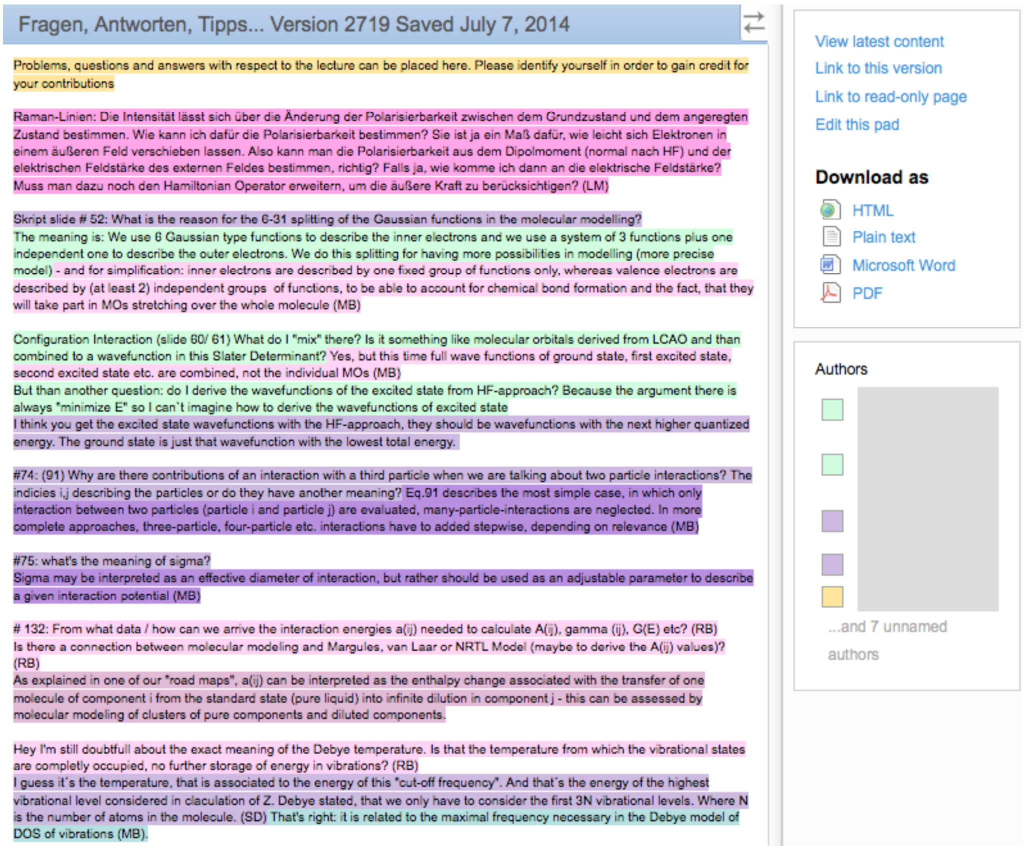

Figure 2. Screenshot of an etherpad dedicated to the discussion of problems with the lecture; author names are greyed out for the sake of privacy

Interestingly enough, the estimated workload for the students in this round with the second group seems to have increased significantly (as measured by asking students to estimate it at examination time). From 140 hrs in the preparational phase of the project, it is now ca. 180 hrs, showing, that the cooperative instruments led to an increase of effort for review and understanding, at least on average. It remains open, whether this did benefit mostly the active contributors, or also the group at large. The overall satisfaction of the students (as judged from the remarks on the evaluation questionnaire) did not change significantly, as well as the examination results (as judged from the average grade and the number of failed exams). A survey after finalization of the project showed an unchanged workload on the somewhat increased level.

3.2. Peer review and bonus systems

It appeared to be a quite strange idea for the students, that contributions in discussions and seminars as well as helpful questions and answers could be rewarded at examination time. Although increased cooperation seemed to be welcome by most of the participants, students felt uneasy with peer review and selection and evaluation of course contents. Figure 3 illustrates this by the average marks students of the second group gave for various aspects of interactivity on an evaluation questionnaire: questions 18 to 20 (concerned with review of peers and contents) got significantly lower average marks than questions 13 to 16 (concerned with the more passive mode of interaction).

When distributing bonus points for examination, the unease with peer review culminated in a move, in which students formed pairs and just exchanged their bonus points, thus effectively avoiding any internal reward and just increasing the chance to pass the exam and get some slightly better final grade. In the comment section of the evaluation questionnaire, some students explicitly suggested, that bonus points should be assigned exclusively by the instructor, so that those class members taking a "free ride" and not contributing can not take advantage of the bonus system. In the third group (17 participants), bonus points therefore were assigned by the instructor, but according to a predefined and agreed list of requirements.

13	Cooperative working with *etherpads* is useful	6	8	1	1	1		2,0	17
14	I could always get help for my questions and problems	6	6	3	0	1	1	2,0	17
15	I was directed to useful tools by group members	3	5	6	3	0		2,5	17
16	Working groups formed easily within the class	4	7	2	3	1		2,4	17
17	I felt comfortable in the group	7	5	2	1	1	1	2,0	17
18	I'd like to help with the selection of additional contents	0	4	9	3	1		3,1	17
19	I'd like to comment and grade contributions of others	2	5	5	2	3		2,9	17
20	I'd prefer online tools instead of a standard lecture	2	4	2	5	4		3,3	17

Figure 3. Part of the evaluation questionnaire for the second group with answers: 34 participants, 17 responses, number of marks given: from "1" (very good, fully agree) in column one to "5" (very bad, completely disagree) in column 5; sixth column: no response; seventh column: average mark

For future development of the instruments tested, it will therefore be necessary to balance the needs of the students with respect to predictability and interactivity: courses with well defined contents and learning outcomes are preferred by the students, but learning enhancements by using instruments fostering interactivity are appreciated as well, as long as they are helping to understand the main programme. For bonus systems rewarding active participation in the course, a transparent evaluation scheme by the instructor will be necessary; engaging students in this process perhaps is too demanding.

Still unresolved is the initial question, whether weaker students or those with very different cultural or language background really benefit from increased interaction and cooperation. The groups in this project were too small to isolate significant subgroups, therefore this question will be one of the most interesting ones in future projects.

3.3. Outlook

The more successful elements of cooperative learning will be introduced in other modules of the author, if applicable, and not only on the level of M.Sc. programmes, but also already in the first year of B.Sc. programmes. Consequently, elements of cooperative learning through social platforms have meanwhile been incorporated on a regular basis into a Physical Chemistry course for freshmen as well as in an advanced course about Chemical Nanotechnology on M.Sc. level. The latter one is also exported into the M.Sc. programme of a cooperating university in Poland (AGH University of Science and Technology, Cracow), so that the tools tested can be developed further from the experience with students with a completely different background. Moreover, trials for an implementation over a network of universities in Germany, Poland, Portugal and France (including elements of distant learning) has just started in the framework of an Erasmus+ -project (InnoChem), led by another partner university from Poland (Politechnika Krakowska, Cracow). In this context, the full integration of graphical and mathematical software (e.g. through iPython notebooks) will be tried out as well.

An alternative approach to gain more time for discussion within the class is the "inverted classroom" concept: parts of the lecture are not presented by the instructor in front of the class, but distributed for individual study, online or offline. Time in class then is used exclusively for working on related problems and exercises. Whether such an approach can work on a subject, that is dominated by mathematical language and strict formalisms, remains to be seen, especially in view of the very diverse levels of prior knowledge that the participants bring into the course. In future courses, it will be checked, how the approaches of cooperative learning tested so far can be complemented by elements of the "inverted classroom".

4. Conclusion

In order to improve the quality of learning in courses concerned with Physical Chemistry, cooperative learning in the class along with the use of interactive graphical and mathematical instruments in principle should offer huge opportunities to overcome the traditional barriers, that many students feel because of the abstract nature of the subject and the need to employ mathematical methods. The project could show,

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that students can be triggered to cooperate more intensely, when suited (software) tools are implemented and added value is experienced, e.g. by bonus systems for the examination phase. Although communication via social media meanwhile is daily business for younger people, such media were difficult to implement as platform for exchange and cooperation. However, a special form (etherpads) was successfully implemented in the target module as well as in related modules. However, it still seems, that stronger students benefit more from such approaches than weaker ones, so the idea to close knowedge gaps by the introduction of cooperative teaching and learning elements did not fully materialize yet and will have to be furthered in future projects.

Bonus systems are only helpful if controlled by the instructor and based on transparent criteria defined before the course starts. In general, students are not (yet) prepared to peer review themselves in the group, and to judge the quality of contributions to discussions and problem solving.

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Student Perspectives of Practical Work done in a Laboratory – a Case Study from Logic Design III

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Abstract

Official accreditation bodies regularly review engineering education programmes to ensure that they adhere to the high standards set forth by the Washington, Sydney and Dublin Accords. These programmes must enable student to demonstrate important graduate attributes such as problem solving, being technologically literate and technically competent, which can be assessed within a laboratory environment. The purpose of this paper is to present student perspectives of practical work done in a Logic Design laboratory with regard to it being enjoyable, beneficial, challenging and relevant to the theory covered in a classroom. An exploratory study is employed along with descriptive statistics involving quantitative analysis of the collected data. Results indicate that the majority of students (45 % strongly agree: 45 % agree) enjoyed the practical work, while many (56% strongly agree: 32% agree) felt that it was beneficial in terms of helping them to understand and apply theory in solving engineering related problems. The majority of students (25 % strongly agree: 47 % agree) further felt that the practical work was challenging, while (51 % strongly agree: 40% agree) agreed that it was relevant to the theory covered in the classroom. However, (41 % strongly agree: 11% agree) of students did indicate that they do not want to submit their practical assignments online. These student perspectives suggest that students are fusing their theoretical and practical knowledge, experiencing a measure of satisfaction as they demonstrate the acquisition of important graduate attributes.

Keywords: *Theory, practice, perspectives, clickers, online submissions.*

1. Introduction

The Central University of Technology (CUT) [1] is a higher education institute providing on-campus contact education (both theoretical and practical) to approximately 13 000 residential students. CUT offers a National Diploma in a number of Engineering disciplines and is therefore mandated by official accreditation bodies, such as the Engineering Council of South Africa (ECSA), to provide quality engineering education programmes which adhere to the high standards set forth by the Washington, Sydney and Dublin Accords [2]. CUT has prescribed ten student graduate attributes which need to be incorporated into the entire curriculum for the National Diploma. Student competency must be demonstrated with regard to sustainable development, problem solving, entrepreneurship, community engagement, technological literacy, numeracy, teamwork, communication, leadership and technical competence. Many of these attributes may be assessed within a laboratory environment, where engineering students are required to fuse their theoretical knowledge with their practical work [3].

Research indicates that African undergraduate engineering students really enjoy their practical work scheduled in a laboratory, feeling that the practical work was very relevant to the theory covered in the classroom [4-6]. However, this was reported on only for students in an electronic communications course, with little results published for students in other engineering disciplines. The following research questions therefore arise: What are the perspectives of undergraduate students with regard to practical work done in a computer engineering environment? Do they feel that the practical work is relevant to the theory covered in the classroom? Do they feel that the practical work was challenging, helping them to apply new knowledge in solving an engineering problem within the laboratory? What do they recommend could be done to improve the practical work done in the laboratory?

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The purpose of this paper is to present student perspectives of practical work done in a Logic Design laboratory with regard to its relevance to the theoretical work covered in the classroom. The research also covers student perspectives with regard to the submission of their practical work via an online learning management system where possible concerns are identified. Reasons for obtaining student feedback are first discussed, along with the importance of fusing theory and practice in any engineering curriculum as mandated by many accreditation bodies, such as ECSA. The perspectives of undergraduate engineering students, enrolled for a module in the National Diploma: Computer Systems qualification at CUT were obtained using a questionnaire administered by means of an electronic response system, which forms part of the research methodology.

2. The importance of student feedback

Literature indicates that the adoption of student feedback was initially a contested topic, where it was mainly used as a performance management tool [7]. However, with the development of various feedback instruments and on-going educational research, it has grown in recognition as a tool to enhance teaching and learning [7]. Student feedback can help to facilitate and organize personalized learning, which is one of the most important research areas in computer based education [8]. Yang *et al*. states that personalized learning is a model where full consideration should be given to learner's personalities [9]. They showed, that in order to effectively realize personalized learning, one should construct the learners' interest and cognitive level models which should lead to the recommendation of specific content based learning resources [9].

Furthermore, Jara *et al*. [10] states that literature is rich with numerous studies and examples of how student feedback can be used to enhance education. In fact, determining student's perceptions by collecting feedback on their experiences is widely recognised as a strategy for monitoring quality of teaching and learning in higher education, and has become a key aspect of quality assurance and enhancement in many UK universities. Emphasis has been placed on integrating it as a regular part of the academic calendar [10]. However, student feedback must be acted upon for it to be truly useful, resulting in a proposed satisfaction cycle, of which a simplified version is shown in Figure 1 [7].

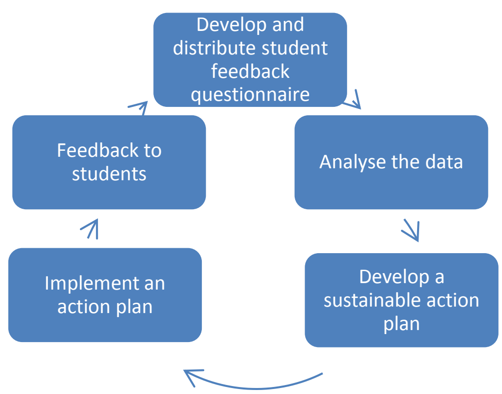

Figure 1. Simplified satisfaction cycle [7]

Care must be taken in the design of suitable feedback questions that would generate relevant data for analyses. When analysing the data, one should focus attention on the use of the results rather than on the results themselves [7]. A successful sustainable action plan should be implemented based on the results, one that includes responsibility, ownership and accountability. Equally important is to give feedback to the students of how their perceptions have been used to enhance a specific module or program, as this would promote future participation.

3. Integrating theory and practice in a Logic Design laboratory

Logic Design III (LOG3) is a semester module on NQF level 6 with 12 credits awarded to it. This means that students need to dedicate at least 120 notional hours to this module over a 14 week period. The purpose of LOG3 is to provide a general introduction to the process of designing digital systems. This is accomplished by introducing the basic concepts of logic circuits and dealing with the synthesis of combinational circuits. The specific learning outcomes of this module gives the undergraduate engineering student the ability to implement digital circuits, making use of different simplifying techniques and various digital devices. Designing synchronous and asynchronous sequential state machines and analysing prototype digital circuits for implementing design-for-testability of various circuits is required. Student assessment focuses on the simplification of Boolean expressions, the design of digital circuits, the design of sequential state machines and analysing and modifying digital circuits. Informal formative assessment, formal formative assessment and formal summative assessments are scheduled and include case studies/simulations, assignments, presentations, peer and self-assessment and written tests and examinations. This module comprises six learning units as indicated in Table 1 which further highlights the link between the theory covered in the classroom and the practical done in the laboratory.

Table 1. Linking theory and practice in a Logic Design laboratory.

	Key theoretical concepts in the syllabus	Practical experiments in the laboratory
Unit 1	Digital design concepts	A simulated real world application design and a VHDL (Very-high-speed-integrated-circuit)
Unit 2	Implementation technology	Hardware Description Language design
Unit 3	Combinational-circuit building blocks	Different ways of implementing circuit designs on a FPGA (Field Programmable Gate Array) Implementing Combinational-Circuit designs on a FPGA
Unit 4	Sequential state machine design	Implementing State Machine on a FPGA
Unit 5	Performance and design issues	Generating simulation waveforms on implemented FPGA programs
Unit 6	Testing of digital circuit	Programming simulated designs on Altera EPM7064SLC44 LAB Board

Practical experiments are done in groups of five and the assignments are submitted online using the Blackboard platform. The purpose of Unit 1 is to introduce to students digital hardware and design processes of digital hardware, simplification and VHDL programming. Table 1 indicates that a real-world application design is linked to this unit, which is preceded by a tutorial. This tutorial comprises a logic diagram schematic entry that must be programmed and simulated. This give the undergraduate engineering student the skills needed to implement a simulated real world application. Unit 2 consists of the theory of transistor switches, CMOS Logic Gates, PLD and optimized implementation of Logic Functions. Please note that the real world application design (from Unit 1) covers minimization and universal properties of gates thus showing different ways of implementing circuit designs on a Field Programmable Gate Array (FPGA). Additional tutorials and assignments indirectly cover different aspects of implementing circuit designs. Unit 3 covers multiplexers, decoders/encoders and multilevel logic design. Table 1 indicates that the practical instruction focuses on designing a combinational-circuit on a FPGA. This is in the form of a very-high-speed-integrated-circuit (VHDL) entry for a multiplexer design. This assignment is preceded by a tutorial experiment where students are shown how to implement a circuit using VHDL entry, generate the waveforms and program the board for demonstration. This again enables the undergraduate engineering students to

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acquire the required skills to complete the assignment on their own in their assigned group. These tutorials consist of an up/down counter with schematic entry and a binary-coded-decimal to a seven segment converter using VHDL. Unit 4 presents information relating to hazards, clock synchronization and asynchronous inputs. These theoretical concepts are covered by all the practical experiments involving simulation waveforms on implemented FPGA programs. Unit 5 includes fault models, complexity of test set, path sensitization, random test, testing of sequential circuits, built-in-self-test and PC board testing. Table 1 indicates that this is linked to practical instruction involving the programming of all the simulated designs on a physical Altera EPM7064SLC44 LAB Board that would require testing and trouble shooting.

The student's final mark consists of a 40% course mark and a 60% examination mark. The course mark is calculated by adding 35% weight for the main theoretical test, 25% weight for different class tests and 40% weight for practical assessments. The practical assessments include practical reports, an individual practical test (assessing the abilities and skills of the individual in a group) and a group practical test (assessing the group's ability to work as a team in a time-limited project). The examination primarily covers theoretical aspects and is completed in a classroom environment.

4. Research methodology

An exploratory study is employed along with descriptive statistics involving quantitative analysis of the collected data. An exploratory design may set the stage for future research and usually involves only a single group of respondents [11, 12]. Descriptive statistics are used as the results are interpreted with regard to specific undergraduate engineering students enrolled at CUT. Quantitative analysis is important as it brings a methodical approach to the decision-making process, given that qualitative factors such as "gut feel" may make decisions biased and less than rational [13]. The target population was restricted to undergraduate engineering students enrolled for LOG3 during 2014. For ease of use and to guarantee student participation, an electronic response system was used in a classroom environment to obtain student perspectives on specific questions relating to the practical work done in the laboratory and its submission via an online learning management system. Closed-ended questions, featuring Likert scales, were used based on previous research which focused on student perceptions of practical work done in a laboratory [4, 5, 14]. Student demography in terms of gender, age groups and home languages are also presented.

5. Results

The purpose of this paper is to present undergraduate engineering students perspectives of practical work done in a LOG3 laboratory. This is divided into three sections; the first focusing on whether students feel that the practical work was enjoyable and beneficial (see Figure 2) and challenging and relevant (see Figure 3); the second focusing on student recommendations regarding the practical work (see Figure 4); and the third focusing on student perceptions of submitting their written practical assignments online via a learning management system.

90% of the students indicated that they enjoyed the practical work (45% strongly agreed and 45% agreed according to Figure 2) which is reiterated by the fact that the majority of the respondents would encourage other students to register for this subject. Results further show that students felt that the practical work helped them to better understand the theory (more than 90% agreed) and that it helped them to apply new knowledge in solving real world engineering problems (55% strongly agreed). This last perception is especially critical as one of the important engineering graduate attributes prescribed by the International Engineering Alliance [15] is problem solving.

Figure 3 indicates that the majority of students (80% strongly agreed) perceived the practical work as being relevant to the theory covered in the classroom. The practical work was viewed as challenging, but not too difficult by the majority of the respondents. This tends to suggest that the practical work enhanced student engagement with the course material [16], leading to a more rewarding educational experience.

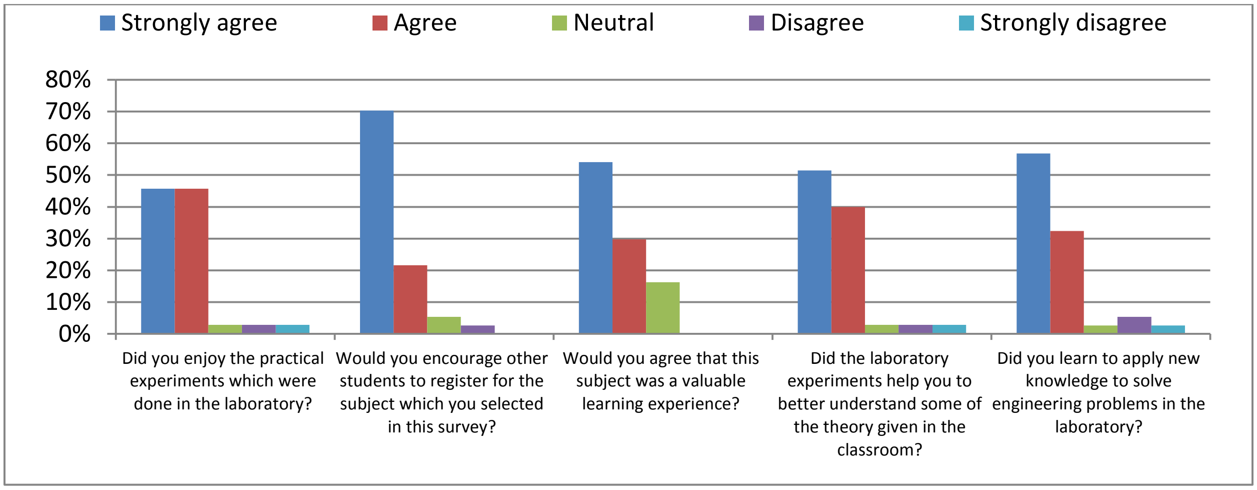

Figure 2. Student perspectives on practical work done in the LOG3 laboratory

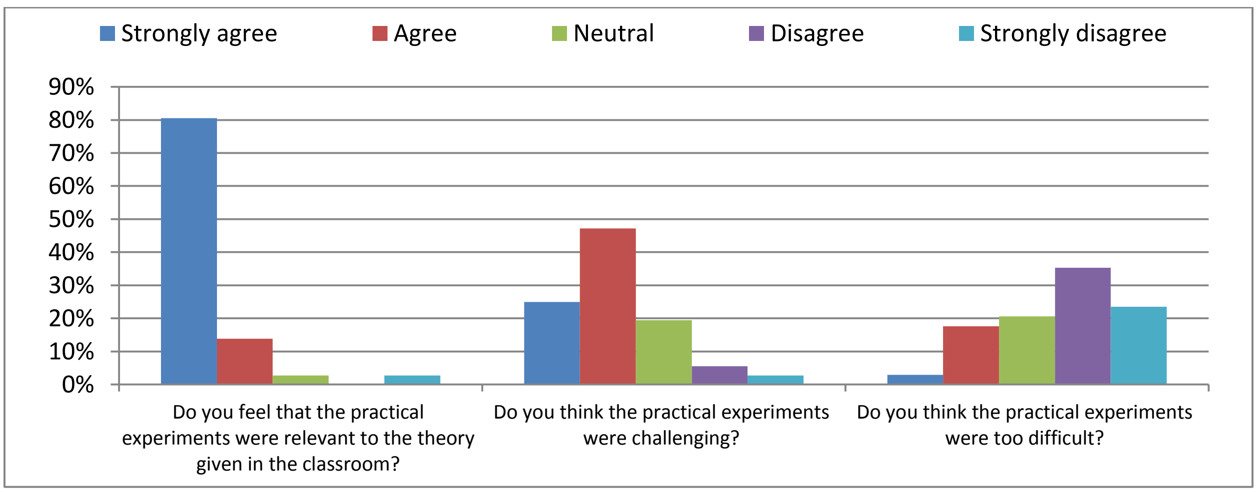

Figure 3. Student perspectives regarding the relevance between the practical and theoretical work

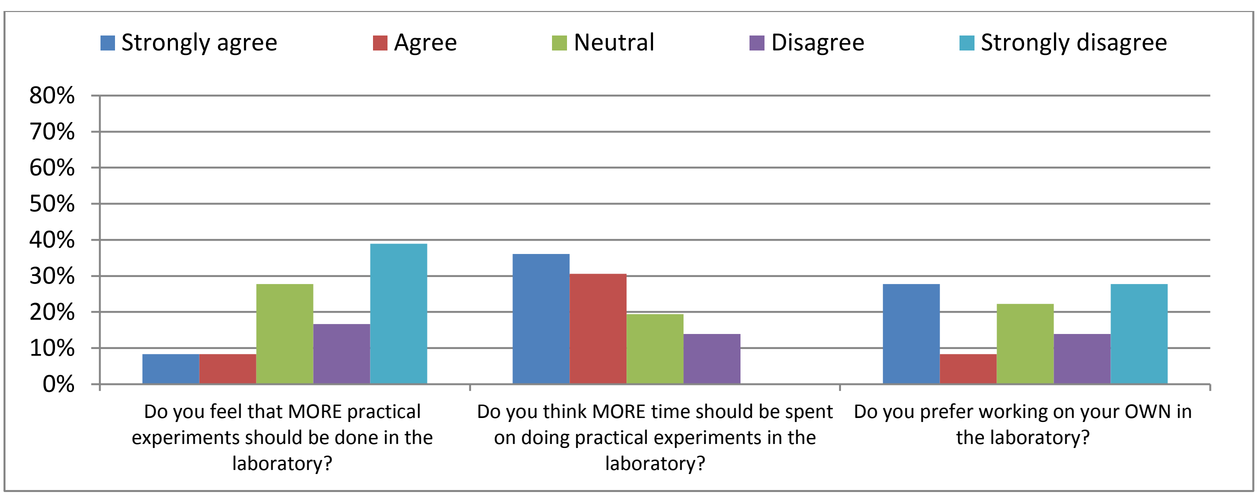

Figure 4. Student recommendations regarding the practical work

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Figure 4 presents some recommendations of students with regard to the practical work. The majority felt that no extra practical work should be scheduled, tending to suggest that the present workload has been well developed to be completed in the 14 week semester. However, many students would prefer spending more time-on-task implying again that they enjoy the practical work and want to further enhance their practical skills. Time-on-task further helps students to make the knowledge their own and create the linkages and relationships within their own data knowledge structures [17]. Mixed opinions exist with regard to group work, with 28% strongly in favour of working on their own and 28% strongly in favour of working in a group. This may be due to the fact that some students feel that they must do all the work, while the other students become passive and just piggyback off the group activities [18]. However, the concept of group work, or teamwork as listed in CUT's graduate attributes, is vital to industry. CUT has regular advisory committee meetings with industry who often indicate that African engineering students struggle to work in groups. Group work must therefore be advocated in engineering curriculum to meet the demands of industry that are in-fact the clients or customers of a UoT.

Figure 5 shows some key recommendations selected by the respondents in a close-ended question. Respondents simply selected those which they felt were important to them. The reason for choosing a close-ended question in this regard is due to the problematic and cumbersome use of an electronic response system when it comes to collecting short sentence responses from respondents. This quantitative data does, however, highlight that many students (30%) want more access to the laboratory during the evenings, while some students did verbally indicate that they would like to access the laboratory more during the day. 24% of the respondents indicated that they would prefer smaller groups in which to work. This may reduce the possibility of piggybacking and help to meet the demands of industry in terms of enhancing student teamwork skills.

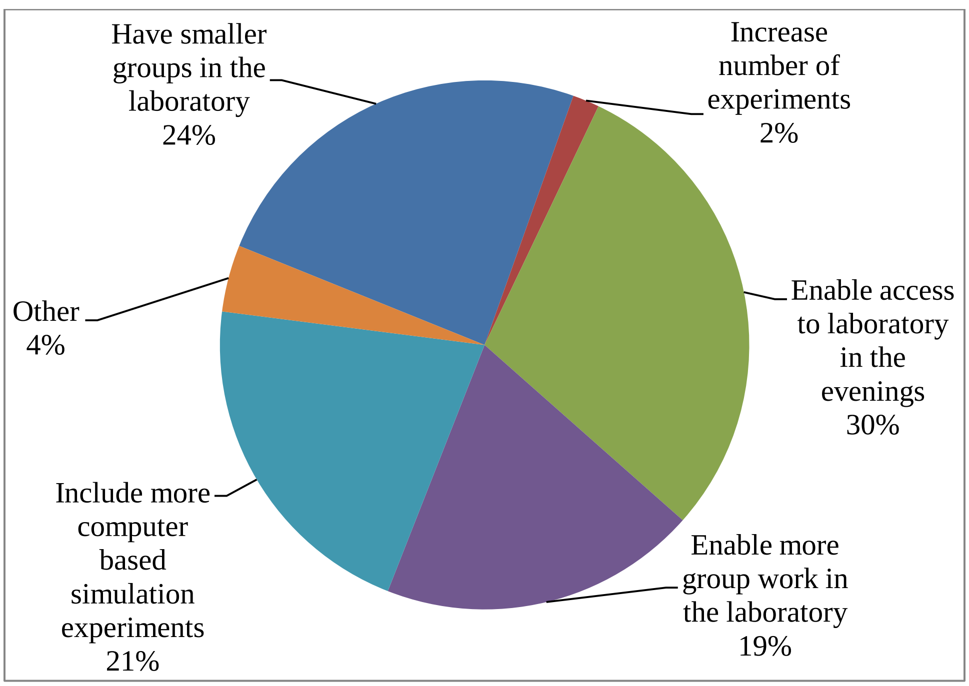

Figure 5. Recommendations from students to improve practical work

The third section, as stated, was to determine the perspectives of students with regard to the submission of their practical work online via a learning management system. It was a surprise to note that the majority of African undergraduate engineering students (more than 50%) would not prefer to submit their practical work online. Figure 6, presenting student selections of pre-defined reasons for not wanting to submit their practical work online, indicate that the majority of students indicated that they have limited computer access and computer skills. These selections

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in a close-ended question were based on previous research done on learning management systems and online assignment submissions [19, 20]. Some of the students verbally indicated that they do not have electricity at home while others fear bringing their laptops to class due to the very real threat of being mugged on public transport systems.

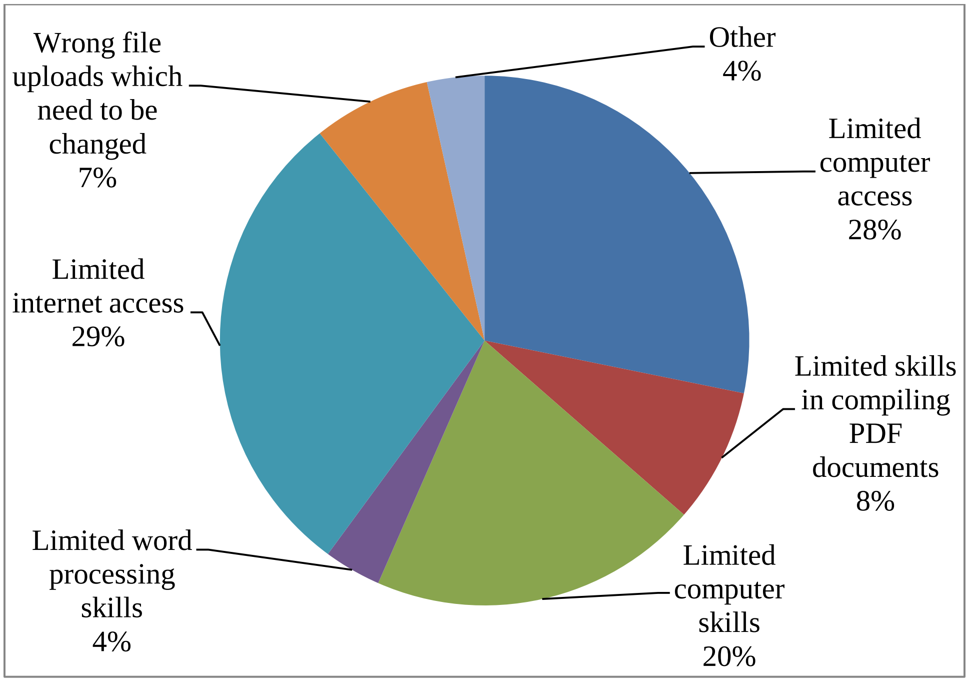

Figure 6. Feedback regarding why students would not want to submit their practical work online

6. Conclusion

It was interesting to note that undergraduate engineering students do not prefer to submit assignments online. Reasons for this included limited computer access, limited computers skills and limited internet access. Students further indicated that they wanted more access to the laboratories. The strongest point of this research was discovering the lack of institutional support expressed in limited computer and internet access.

This can be addressed by reiterating to students the availability of online open computer laboratories and how to access them. Offices of lecturer assistants have also now been established in the laboratories in order to provide students with more opportunities to access the laboratories, especially during the evenings. High impact programs are planned for 2015 which will focus on MS Office software, report writing and the processes of online submissions. Kuh [21] widely tested high impact programs and demonstrated that they are beneficial for higher education students from diverse backgrounds. It is important to bear in mind that not all students are technologically literate as shown by Swart [20], and would therefore require training in accessing and using these online open computer laboratories. The inclusion of a practical tutorial in the course content which is specifically designed to address this need is warranted.

Industry indicated at an annual advisory committee meeting that newly appointed African engineering students struggle to work in groups. To address this concern, group work was introduced in LOG3. A group of five students would choose a leader, a company name and then design a logo to simulate the company. However, results show that not all students prefer working in groups as they feel that they must do all the work while other students simply piggyback (parasite marking results). Additional research into student perspectives regarding why they differ on the use of teamwork merits further consideration, especially since it has become an accepted norm in many industries. Possible recommendations include incorporating peer assessments and introducing additional high impact programs focusing on how to work in groups. Other possible recommendations may arise from the additional student

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perspectives which should be sought regarding individual or group work. Nevertheless, the present student perspectives do suggest that students are fusing their theoretical and practical knowledge, experiencing a measure of satisfaction as they demonstrate the acquisition of important graduate attributes mandated by many accreditation bodies in the world.

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Experimental Centric-Based Instructional Pedagogy

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Abstract

This paper describes a project of cooperation among thirteen (13) Historically Black Colleges and Universities (HBCU) electrical and computer engineering programs. The intent is to develop an HBCU Engineering Network (HBCU-EngNet) with focus on the development, implementation, and expansion of an Experimental Centric based instructional pedagogy (ECP) in engineering curricula used in these HBCUs. The outcome of such cooperation is nothing less than the production of a larger number of better prepared African American engineers, as well as other students who have a better public understanding of technology and its role in (science, Technology, Engineering and Mathematics (STEM), education and policy. The ECP is being implemented at the various HBCUs to allow students of varying learning styles the opportunity to learn at their own pace and in their own environments, by providing them an alternative way to acquire technical skills and knowledge both in the classroom and outside.

We describe the various learning modules developed by the HBCU networks covering courses in Electrical and Computer Engineering (ECE) first two years curriculum: Introduction to Electrical Engineering, Electric Circuits and Lab, and Electronic Circuits and Lab.. We build on the ECP courses that have already been developed, evaluated, and adopted at Howard University and Morgan State University, with an established National Science Foundation (NSF) funded Engineering Research Center (ERC) at Renssalaer Polytechnic Institute (RPI).While these courses were developed using the Mobile studio, the new ECP based learning modules have been developed using the Analog discovery boards. Faculty members of each member HBCU shares their labs and class activities through a set of hands-on face-to-face training workshops that is held at Howard University campus in the fall and in the summer. We have also conduct bi-weekly online training workshops, meeting with guest speakers' talks via webinars and video conferencing tools. We also have online site to host documents, activities, online resources and best practices. We will report on preliminary assessment results of student learning and conclude on describing lessons learned and the next steps of this project for improvement.

Keywords: *engineering, network, cooperation, electrical, computer, analog, discovery, assessment.*

1. Introduction

The continuous improvement or advanced standards of the citizens of any nation depends on continuous research. For many decades the US has continued to enjoy the global leadership role in developing and implementing cutting edge research [1] in universities and other agencies. However, there are few underrepresented minority groups of researchers. The contribution of a diverse population of scientists and engineers is necessary to meet the world's competitive environment in technology and research for development. Presently, very low percentage of under-represented groups participate in research. According to the US census bureau underrepresented groups will make about 48% of the workforce by the year 2050 as opposed to 26% in 1995. There is always a need for more science, technology, engineering and technology (STEM) workforce. At the moment STEM labor force is mostly white. However, there is a talented underrepresented group that needs to be tapped and trained for research and improved

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technology. The main funding sources for research include the National Science Foundation and other federal government agencies such as Department of Defense

This paper discusses how undergraduate students (especially in Historically Black Colleges and Universities, HBCUs) are introduced to how pursue STEM areas in college academic in an innovative way under the guidance of the engineering faculty in collaboration with other HBCUs. Students with experience background in STEM areas will generally increase their employability chances.

2. The Importance of the Experimental Centric Based Pedagogy Program

For time first time HBCUs are collaborating to unify electrical and computer engineering in their programs to collectively enhance the recruitment , retention and the efficient graduation of their students through centric based pedagogy. This program is supported by the National Science Foundation (NSF) The objective is to make a significant contribution in the US STEM workforce. Efforts in increasing home grown STEM professional s will minimize exporting STEM based jobs to foreign countries and to ensure strong economy in the global community. Presently, under represented minority with interest in STEM areas) graduation rates are rather low compared with others as the table [5] below indicates:

Table 1. Bachelor of Science (BS, STEM) Degrees Graduation Rates for Various Groups

Ethnicity	4-Year Completion Rate (%)	5-Year Completion (%)
Native American	16.8	33.2
African American	21.0	35.6
Latino	25.8	44.0
White	42.6	60.2
Asian-American	44.9	66.0

As can be seen from the above table, no matter which way one observes minority groups still lag behind other rates even though graduation rates for all groups increase with 'more' years of completion than standard 4-year program. Thus the experimental centric based program main aim is to enhance minority programs through recruitment, retention and study habits in STEM and increase their graduation rate. Currently, HBCUs produce 23% of under represented groups in the STEM areas. The number is rather minimal and must be improved. It is proposed to increase their number projected by 10% by the year 2020 [5] through the experimental centric based program.

A common framework is needed and advantageous so that all STEM programs can share their efforts to increase numbers of BS engineering STEM numbers. A general effort of the Experimental Centric Pedagogy (ECP) program is to make it adaptive to several variety of fields that will engage and stimulate interest of minority groups especially in STEM areas.

Presently, Thirteen (13) HBCUs (shown in table 2 below) are participants of the ECP [5] . Howard University, Washington, DC and Morgan State University, Baltimore, Maryland are the lead universities. Digilent Inc is the main advisory industrial member.

Table 2. ECP Thirteen(13) HBCUs Members

Institution	**Location**
Alabama Agricultural and Mechanical University	Huntsville, Alabama
Florida Agricultural and mechanical university	Tallahassee, Florida
Hampton University	Hampton, Virginia
Howard University	Washington, DC
Jackson State University	Jackson, Mississippi
Morgan State University	Baltimore, Maryland
Norfolk State University	Norfolk, Virginia
North Carolina Agricultural and Sate University	Greensboro, North Carolina
Prairie View Agricultural and Mechanical University	Prairie View, Texas
Southern University A & M College	Baton Rouge, Louisiana
Tennessee State University	Nashville, Tennessee
Tuskegee University	Tuskegee, Alabama
University of Maryland Eastern Shore	Princess Ann,, Maryland

Table 3. Non-HBCUs Participants

Institution	**Location**
Rensselaer Polytechnic Institute (RPI)	Troy, New York
Wright State University	Dayton, Ohio
Virginia Tech University	Petersburg, Virginia
University of Albany, SUNY	Albany, New York
National Council for Minorities in Engineering	White Plains, New York

Other advisory board members include but not limited: IBM, Intel, FLUKE, Freescale, KEYSIGHT, Texans Include Instruments, National Instruments, others

The ECP program allows students to learn at their own pace in their own environments. Study modules have been developed, adopted and placed on line for students and faculty access. Most modules in electrical and computer engineering present hands on approach coupled with lectures using the 'analogy discovery' a personal

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instrumentation equipment that is an expensive portable lab . It contains function generator, dc power supplies USBN cable attached to a PC that serves as instrumentation (voltmeter, ammeter, 2-chaneel scopes). The terminals of the analog discovery are wire coded. It is small instrument about half-palm size. See figure 1 below showing the analog discover and its application. This inexpensive new tool replaces the traditional bulky expensive and not enough space for all student participants. The partners also conduct workshops on line periodically (generally twice a semesters) using video-teleconferencing coupled with weekly meetings on line.

In future, as the network matures , the curricula can be shared by the global community and to sustain the network and its impact. The ECP initiatives will certainly enhance the learning capabilities of under represented groups for the dissemination of STEM programs.

3. Laboratory Equipment and Analog Discovery

The analogy discovery is a portable inexpensive lab that can be adapted to suit several hands on experience in several scientific and engineering disciplines. It combines hands on and lectures simultaneously. It eliminates the need for several bulky classical lab equipment.

It can be used for analog or digital systems. It is portable and it can fit in a pocket or backpack. See its use in Figure 2. Traditional labs are equipped with bulky work benches and large expensive instruments and other equipment (such as large function generators , oscilloscopes and power supplies) as shown in Figure 1, sources that consume a lot of electric energy for operation. Due to limitation of space and bulky equipment, students work in large groups.

Figure 1. Old Fashion Traditional Lab

Concept-Bulky

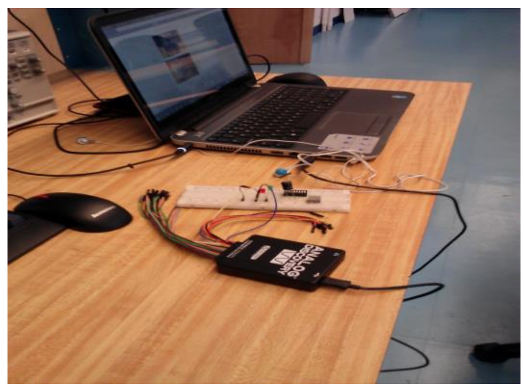

Figure 2. Analog Discovery set up

The analog discovery is a very inexpensive mini portable analog and digital lab device (that serves as a personal instrumentation) It measures 2.5"Wx3"Lx1/2"D. It can fit in the palm. It consists of a dual oscilloscope, function generators (provides variable voltage 0 to 5V=, or 5V-), 16 channel digital logic analyzer, dual dc power supplies (5V+ and 5V-) and it is USB powered. It also has a room for headphones so the user can listen in to the circuit operations. See figure below being used by a student in circuits class. Circuit board connects to the color coded terminals for easy application. (for example the two voltage terminals are 1+, 1-, 2+, 2-. See wires color code in Table 1. The color code is used for proper connections to the bread board. It can be used for several labs in sciences with a transducer interface.

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Table 3. Analog discovery Wire Color Code

Mode	Color	Ground
Scope Channel 1 Positive Negative	 Orange Orange/white	black
Scope Channel 2 Positive negative	 Blue Blue/white	black
Power supply (dc)		
V+ 5V V- -5V	Red White	
Waveform generator 1 **Trigger in**	Yellow Grey	black
Waveform generator 2 Trigger in	Yellow/white Grey/white	black
Digital I/O Signals	Pink, green, brown, purple, all with white stripes	

The mobile studio is a similar personal instrumentation device as the analog discovery . Requires more wiring than the analog. It is slightly more expensive.

Sample Lab-hands on Module [10]

Taken from 'Electrical Engineering Practicum'

Format

Theory:

The theory discusses what the hands on lab is about with technical equations and circuit diagrams

Lab Exercise:

Contains schematics and step by step approach to the lab

Video:

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The video gives additional from a demonstrator (instructor) how the circuit should n e wired on a bread board and what the circuit should like physically and the expected data, analysis (interpretation) of the results.

4. Smart Lighting Institute Outreach Program

The engineering and science communities in the US are trying several methods of introducing high school students (especially under-represented groups) to STEM undergraduate education to motivate them become future researchers and educators. [2]. Howard University, is one of the Historically Black Universities and Colleges (HBCUS) that offer advanced degrees including doctoral (PhDs) in electrical and computer engineering. We have several advanced research centers on campus with outreach programs as part of community engagements. High school students are recruited to attend STEM programs such as the Smart Lighting Institute.

Smart Lighting Institute Activities: Activities include principles of electrical and computer engineering, hands on projects with the use of LEDs and solar panels, use of mobile studio and the analog discovery for their activities. field trips where solar panels are being used, team work, communications and oral presentations of work done. It is a 4-week program in summer. The program ends with a final presentation to parents at a closing ceremony.. Program assessment includes: the participants input for the strengths and weak points of the program for future upgrades. Our aim is to introduce under-represented high school students to pursue STEM areas in their college education and make contribution to the respective profession. Figure 3 shows smart lighting summer program high school students on a field to an application of renewable energy (solar power) powered school building. Figures 4 and 5 show high school students projects presentation.

Figure 3. Smart Lighting Students on a field trip

Figure 4 Smart Lighting Projects Presentations

5. Experimental Centric-Based Instructional Pedagogy Assessment (HBCU Sample Survey)

Pre- course and post-course survey (pre-survey and post-survey) are done for each course to study impact of the program on the students before the course begins and at the end of the course. The results and recommendations are assessed and implemented with improvements in future course offerings.

The surveys cover:

a. Personal data: name, institution, other

b. Learning preference: instructor giving examples, on line , lecture and demonstration, individual and teamwork, hand on, in class as well as outside the class

c. prior experience: traditional instruments (e.g. scope, function generator, power supplies), mobile learning (e.g. analog discovery, mobile studio), circuit building, on line video lectures

d. Engineering knowledge: perception, skills, preparation

   (i) ability to apply scientific knowledge to engineering tasks

   (iii) Ability to design experiments

   (iv) Ability to interpret data

   (v) Ability to function effectively on a multi-disciplinary team

   (vi) Ability to communicate effectively as public speaker

   (vii) Knowledge of contemporary issues.

e. Overall: Experience with increased hands on to enhance professional abilities

f. Confidence: in engineering prior to start program and after.

We obtain positive survey results pre and post of the ECP program in STEM.

6. Conclusion

We introduce a common core knowledge for Historically Black Colleges and Universities STEM education programs in the US to the under represented groups overall percentage output of graduates and how to motivate them. Thirteen HBCUs are participants together with other non-HBCUs. The analog discovery is introduced as a personal instrumentation for hands on individual or group assignments. Surveys are carried out before and after a course is taken. The survey predicts their future skills in the STEM profession and how they can contribute to the global community for economic development. On line study modules are implemented for the individual students. They can also learn at their own pace. It is anticipated that the program will be adopted by several institutions.

7. Acknowledgements

We thank students and staff for their contributions in the upgraded lab using the analog discovery and the development pf the ECP program. We also like to thank the Smart Lighting research group of Rensselaer Polytechnic Institute (RPI) support and the National Science Foundation (NSF for their support).

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Figure 5. Smart Lighting: Closing Ceremony-Students Final presentations

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Effectiveness of student- and professor-centered learning in the geotechnical engineering introductory course

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Abstract

Identifying effective learning and teaching styles in engineering education is challenging because many students lack systematic background knowledge, which adversely affect their enthusiasm and motivation for learning. Presently, there is a variety of methods that professors and instructors utilize in order to help students learn. Geotechnical engineering is a unique discipline in civil engineering that poses additional challenges while providing opportunities for development of more effective teaching and learning strategies. Therefore, a study was conducted to assess the effectiveness of currently employed student-centered (SCL) and professor-centered learning (PCL) methods. A hypothesis was made that SCL is more effective than PCL. This hypothesis was tested and confirmed by analyzing assignment grades requiring SCL and PCL. However, SCL in the analysis occurred only in a laboratory setting. Students indicated that having laboratory and recitation sections offered in the same semester increased their motivation and enthusiasm. As a result of research findings, changes are being planned for future implementation. Specifically, the course is being significantly restructured so that SCL and PCL for each topic are better synchronized and interconnected. The goal of this effort is to better prepare students for SCL so that they infuse enthusiasm and motivation into PCL events. Additional modifications of PCL will include more referrals to laboratory experiments.

Keywords: *Geotechnical Engineering, Student-Centered Learning, Professor-Centered Learning*.

1. Introduction

Teaching and learning in academic disciplines of science, technology, engineering, and mathematics (STEM) are particularly challenging because STEM disciplines require systematic background knowledge that many students do not possess. This lack of knowledge may be a contributing factor to students' struggles to grasp introductory civil, mechanical, and architectural engineering courses, such as statics, thereby adversely affecting their enthusiasm and motivation for learning.

In the introductory geotechnical engineering course, additional obstacles are often encountered due to the unique nature of the course compared to other civil engineering courses. Geotechnical engineering addresses properties and behaviors of soils and rocks as they relate to the civil infrastructure. However, unlike other civil engineering materials, soil and rock are not manmade materials, so they exhibit far more complexities. For example, soils are multiphase materials consisting of solid particles, pore water, and pore air. This complicates flow of fluids and transfer of external loads. Geotechnical engineering also requires an interdisciplinary approach that involves knowledge of physics of solids and fluids, mathematics, and sometimes chemistry. Finally, good geotechnical engineering designs and solutions are not easily visible; they are hidden underground. Conversely, only bad designs and failures expose the significance of geotechnical engineering, such as the infamous leaning tower of Pisa. Consequently, students often do not recognize the importance of geotechnical engineering, thereby diminishing their enthusiasm and motivation for learning.

The unique, challenging nature of geotechnical engineering also provides opportunity for development of more effective teaching and learning strategies. A significant amount of research related to engineering education has been conducted in the last two decades in order to improve teaching and learning efficiency. Engineering professors and instructors currently utilize a variety of methods in order to help students learn [1]. Professor-centered learning (PCL), also known as traditional education, requires the professor or instructor to have a primary, active role, while students have passive, receptive roles. Research results have shown [2] that PCL alone is not sufficient to achieve learning excellence in engineering courses.

Student-centered learning (SCL) emphasizes the student as the center of the learning process. In the past, several methods have been applied to study the effectiveness of SCL in geotechnical engineering education, such as

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poster presentations [3], self-teaching handouts [3]-[4], and group projects [5]-[6]. Results showed that SCL increased student satisfaction and motivation and helped students more effectively learn course theory compared to only PCL. However, students often perceive the introductory course of geotechnical engineering to be less structured than most civil engineering courses. Therefore, PCL must be retained for that course in order to provide additional course structure, allow opportunity for presentation of important theoretical concepts, and help students develop problem-solving skills.

A comprehensive study was performed to evaluate effectiveness of current PCL and SCL events. The primary objective of the study was to determine the most effective setting for learning based on identification of further improvements in teaching methodology. Specifically, the ultimate goal was to cross-pollinate the less effective learning setting with student motivation, enthusiasm, and joyfulness contained within the more effective learning environment. The study was based on two methods of analysis: 1) objective evaluation of learning through analysis of student grades, 2) subjective evaluation of teaching and learning through direct student input using a questionnaire.

Following the introduction presented in this section, a detailed description of the course structure is provided in Section 2. The hypothesis of the study and a comprehensive review of statistical results are given in Section 3, and Section 4 provides overview of subjective evaluation of teaching and learning. Finally, study findings are summarized in Section 5.

2. Description of CE522 Soil Mechanics 1

A comprehensive study was performed of CE522-Soil Mechanics 1, the mandatory three-credit-hour introductory geotechnical engineering course offered to juniors and seniors in Civil and Architectural Engineering at Kansas State University. In addition to recitation, the course also includes laboratory exercises. Main topics of the course include phase relationships, index properties, soil classification, steady state seepage, stresses in soil mass, consolidation, compressibility and time progress of settlement, and shear strength.

For the purpose of accreditation by the Accreditation Board for Engineering and Technology (ABET), the educational objective of CE522 is to ensure that students become successful in civil engineering careers. Consequently, upon successful completion of this course, students should be able to: 1) apply mathematics, science, and engineering principles, 2) design and conduct experiments and analyse and interpret data, 3) identify, formulate, and solve engineering problems, and 4) communicate effectively. In addition to CE522, other classes in the civil engineering program also address these outcomes.

CE522 includes four types of assignments (homework, quiz, laboratory reports, and exams) of which the grades contribute to 10%, 15%, 15%, and 60% of the final grade, respectively. All assignments are designed to test knowledge acquired by the students. SCL occurs only during laboratory sessions in this course. Five laboratory exercises cover 1) sieve analysis and determination of water content, 2) laboratory compaction test, 3) permeability tests 4) one-dimensional consolidation test, and 5) shear strength testing. A laboratory manual for each laboratory exercise is posted online prior to the scheduled exercise, thereby enabling students to be prepared for each laboratory exercise. A Teaching Assistant (TA) provides an additional brief explanation at the beginning of each laboratory session. Students are typically divided into 6 groups consisting of 6 or 7 people in each group. Each group must complete its own task during the given laboratory session, utilizing interaction between all group members and interaction with the TA if necessary. The TA is a facilitator that offers advice and suggestions as needed. After each laboratory exercise is completed, each group must submit the corresponding laboratory report. The grade for all laboratory reports was then used as evaluation of SCL effectiveness.

However, knowledge testing that occurs through homework, quizzes, and exams evaluates learning acquired primarily during recitations, which are PCL events. Although additional learning likely occurs outside the classroom, unlike the laboratory sessions, PCL is primarily utilized in relation to knowledge tested through homework, quizzes, and exams. Therefore, these testing methods were used to evaluate the effectiveness of PCL. Accurate determination of the number of group activities and amount of SCL occurring during homework completion is difficult because students are encouraged to discuss homework problems together. Therefore, in order to retain objectivity in this study's analysis, all homework grades were excluded from the analysis. However, group work was inherent to SCL during laboratory exercises.

3. Study Hypothesis and Statistical Hypothesis Testing

As stated, the hypothesis of this study was that learning derived from SCL events is more efficient than learning resulting from PCL events. In order to evaluate this hypothesis, student grades from SCL events were compared to grades from PCL events. In order to determine if the probability of a given hypothesis is true, a statistical hypothesis testing of the grades was performed. For preliminary analysis with results presented in this paper, grades from assignments involving SCL and PCL categories were collected for three semesters: Fall 2011, Spring 2013, and Spring 2014.

The first step of any hypothesis testing is to state the relevant null (H_o) and the alternative hypothesis (H_1). The null hypothesis is the hypothesis associated with a contradiction to the theory to be proven. In this study, the null hypothesis was that grades from PCL events are better than grades from SCL events. The alternative hypothesis is the hypothesis that one would like to prove. In this study, the alternative hypothesis was that grades from SCL events are higher than grades from PCL events.
After null and alternative hypotheses were formulated, one-sample *z*-statistics were calculated from collected data. The *z*-test statistics were then converted to a conditional probability called a *p*-value, which was compared to a significance level (α), a probability threshold for a decision. If *p* - value was less than and equal to α, the null hypothesis was rejected and the alternative hypothesis was proven to be true. The significance level was selected before data analysis began, and it was chosen to be equal to a usual value of 0.05 (5%). Data obtained after analysis was completed is shown in Table 1.

Table 1. Statistical Hypothesis Testing Results

Semester	Assignment	*z*-value	*p*-value
Fall 2011	Quiz	15.624	< 0.00001
	Exam 1	2.462	0.006908
	Exam 2	9.521	< 0.00001
	Exam 3	12.741	< 0.00001
	Final Grades	10.684	< 0.00001
Spring 2013	Quiz	11.362	< 0.00001
	Exam 1	6.570	< 0.00001
	Exam 2	4.508	< 0.00001
	Exam 3	3.549	0.000193
	Final Grades	7.080	< 0.00001
Spring 2014	Quiz	3.373	0.000372
	Exam 1	8.962	< 0.00001
	Exam 2	7.519	< 0.00001
	Exam 3	10.075	< 0.00001
	Final Grades	10.334	< 0.00001

As shown in Table 1, obtained *p*-values for each assignment and semester were substantially lower than the preselected significance level, 0.05. Therefore, the null hypothesis was rejected and the alternative hypothesis that learning occurring during SCL event is more efficient than learning during PCL events was proven statistically to be true. Even if the significance level were decreased to a more rigorous value, such as 1%, the *p*-value would still be less than the significance level, resulting again in proving the alternative hypothesis to be true. In summary, the hypothesis that SCL is more effective than PCL was proven.

4. Subjective Evaluation of Teaching and Learning

A questionnaire was designed to survey students regarding their experiences in CE522, the introductory geotechnical engineering course. Answers clearly showed that students had limited a priori interest in geotechnical engineering (Figure 1.a). However, student interest and appreciation of geotechnical engineering changed significantly after enrolling in the class (Figure 1.b). Results also showed that laboratory exercises that engaged students in SCL significant impacted development of student enthusiasm and motivation. Specifically, students found laboratory exercises to be enjoyable, useful, and less stressful learning environments (Figure 1.c-1.e). Students also preferred having laboratory exercises (SCL) and recitation (PCL) offered in the same semester (Figure 1.f). It is noted that the students had have prior experience in Mechanics of Materials whereby laboratory and recitation were offered as separate classes, which are not always taken during the same semester.

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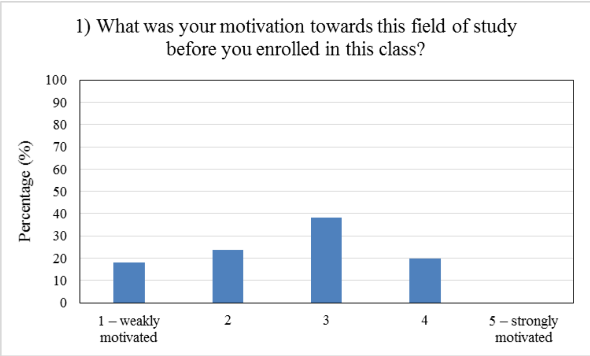

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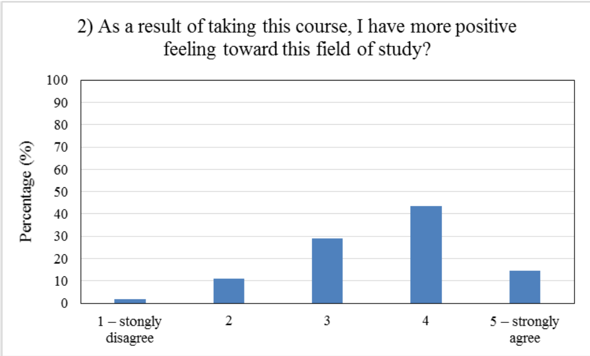

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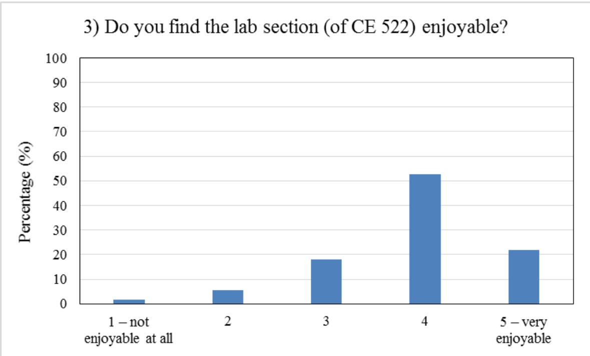

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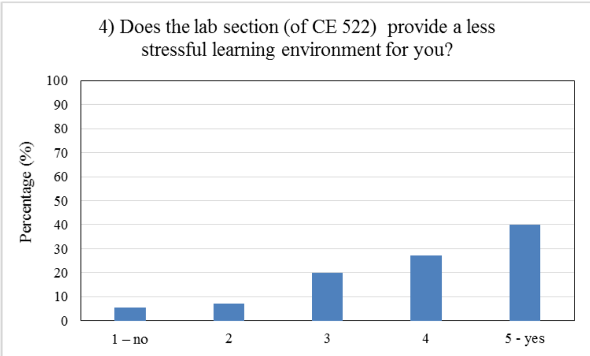

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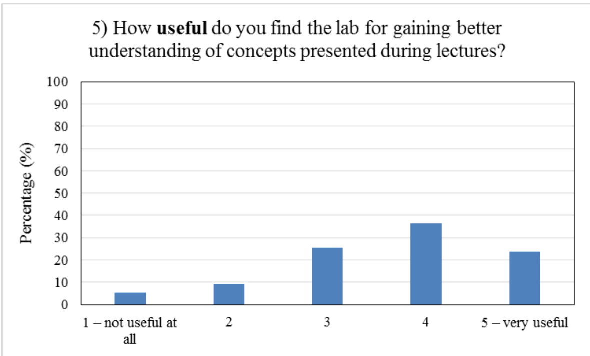

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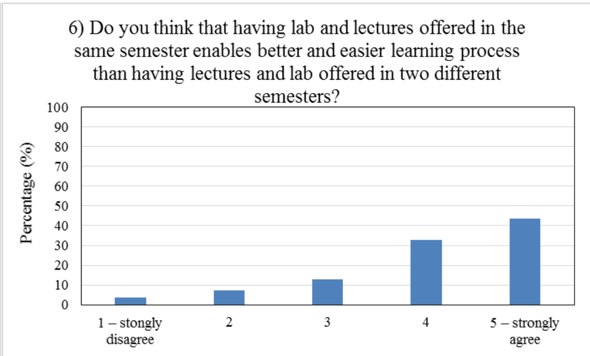

f)

Figure 1. Extract from Student Questionnaire

In the questionnaire, students were also invited to provide comments and suggestions regarding how to increase teaching and learning efficiency. The most often-encountered suggestion was to better synchronize materials presented during the recitation (PCL) and laboratory exercises (SCL). Specifically, students desired timely theoretical introduction to laboratory exercises.

5. Conclusion

Statistical analysis of student grades in various assignment categories showed that traditional teaching, or PCL, is less effective for student learning than SCL, thereby providing opportunity for improvements in overall learning effectiveness in CE522, the introductory geotechnical engineering course. Specifically, student activities that occur during laboratory exercises and writing laboratory reports enable students to actively participate in their learning. Students also indicated that the opportunity to take laboratory exercises with recitations in the same semester is useful and provides additional motivation for learning as well as a less stressful and more enjoyable learning environment.

These preliminary statistical results based on data collected over three semesters indicated that changes in teaching methods should be implemented to improve teaching and learning effectiveness. Although final changes will be formulated upon the completion of analyses of additional semesters, various improvements can be presently implemented. First, laboratory exercises should be better synchronized with recitation. Because of the limited number of credit hours available for this course, the last laboratory session will likely have to be

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moved into the subsequent undergraduate geotechnical engineering class. Students expressed appreciation for the PCL aspect of CE522 because the professor provided timely theoretical explanations for upcoming laboratories. Therefore, in order to infuse the enthusiasm, effectiveness, and joyfulness of SCL, laboratory test results will be presented during recitations whenever they are directly relevant, thereby providing opportunities to connect underlying physics and, associated mathematical descriptions and subsequently implement this knowledge into problem-solving skills. This improved interconnectedness between SCL and PCL is anticipated to lead to development of more creative and original problem-solving skills for students. In summary, cross-pollination between SCL and PCL is expected to improve overall effectiveness of teaching and learning in CE522, the introductory geotechnical engineering course.

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Toward a more practical Engineering Curriculum

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Abstract

When students matriculate in the Engineering department at the University of Pittsburgh, they will be required to do a Freshmen project as a team member, in the first semester. This usually requires a fair amount of practical knowledge. However is it enough to realize, what are the practical implications in every course area? It is kind of a shock to realize that many students have no idea what a resistor looks like, what happens when a capacitor charges, why Thevenin's Theorem is so powerful, why a digital counter operates as it does and one could go on and on with dozens of other examples. Starting in the fall semester of 2014, teams of 2 or 3 students are required to present to the Professor a practical example of a circuit or theorem discussed in theory. It has to be on a breadboard with its own on board power supply, has to show in certain cases output using LED's, and requires a one or two page explanation of the theory involved. 10% of the semester grade will be dependent on a proper presentation of a practical example and if a presentation is not forthcoming a group of students will forfeit the 10% of their grade. After their sophomore year students are urged to sign up for the coop program and a majority of them do. Here they obtain valuable practical work experience during their semesters on the job, most often are hired by the company they are working for as a student and get a good wage for their efforts. The above of course is based on an Electrical Engineering program but can be just as well formulated for any other Engineering discipline, The extra work involved in monitoring the simple projects of the student groups will show up in a better understanding of the theory of each course

Keywords: *Practical Engineering, Electrical Engineering, Coop Program*

1. Introduction

As was pointed out in the abstract several practical exercises are incorporated into the Freshmen Engineering course in the first semester. Teams of students have to design and construct a project of their choosing which has to be approved by the professor. To make sure that the exercise is worthwhile to the students, proper completion of the projects is 25% of the course grade. The whole campus is invited to see what the Freshmen Engineering students have been up to and as can be seen from the two samples of last fall's semester projects, the students put a lot of time and effort into these exercises. Many hours are spent in designing, obtaining parts, building and modifying the project and in some cases starting all over. Practical tools can range from woodworking equipment to welding equipment to machine shop applications. Soldering is quite often necessary and knowledge of small engines and their modifications have to be applied in some cases. [1] [2] [4]

At midterm of semester one each team of students participates in an egg drop contest, where contraptions that will protect an egg are launched from the roof of the Engineering building. Each team of contestants is judged on three categories. Weight of the contraption, number of parts used to protect the egg and the time it takes from the roof to the ground. All of this data is put into an equation and then it will be determined who the best three teams are. Prizes of $150 for first place, $100 for second place and $50 for third place will be awarded. Here again it takes some practical know how to judge what to use for parts, how to minimize weight and how to make sure of a minimum time to reach the ground. [2]

In addition to the aforementioned projects and exercises, the course where all of this takes place includes a laboratory session of an hour and a half each week. Here numerous topics are explored and a laboratory notebook has to be kept. The laboratory exercises could be grouped into three or four different categories. Electrical, Mechanical, Civil and Computer setups are required and involve simple test equipment and parts provided by the instructor. Ohms Law and using a Digital Multi Meter (DMM) gives students the ability to make basic electrical measurement on simple circuits. Another quasi electrical laboratory gives students the ability to understand the basic operation of an oscilloscope and that it is used in different Engineering areas and with external changes can even be used in the medical field. Students will team up for several laboratory sessions in surveying where they survey parts of the campus and additionally make vertical measurements using a Theodolite. Stress and Strain analysis is done on typical steel and aluminum samples where an analysis is done in one case on computer controlled equipment, while in another case the equipment is manually controlled, and students have to construct graphs of stress versus strain using Excel. A Virtual laboratory shows students that in some cases this might be a preferable method to conduct a laboratory where possibly a hands on way of making measurements could be too dangerous or that the actual equipment that has to be used would be too expensive, and then a virtual laboratory can be a reasonable alternative. [3]

These are the two samples of the Freshmen projects mentioned previously and show two completely different approaches to the assignment. One is very high tech with much of the information obtained from the Inter-Net, while the other required welding, Rototiller repair and some ingenious fitting for steering. [1]

Figure 1. The cheap cross country vehicle

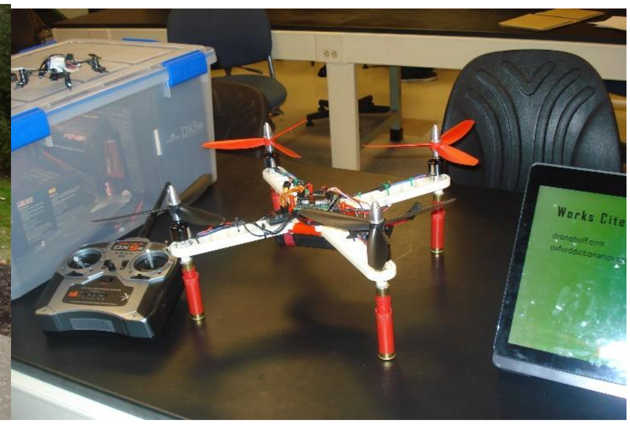

Figure 2. The Drone

Figure 3. The Drone in flight

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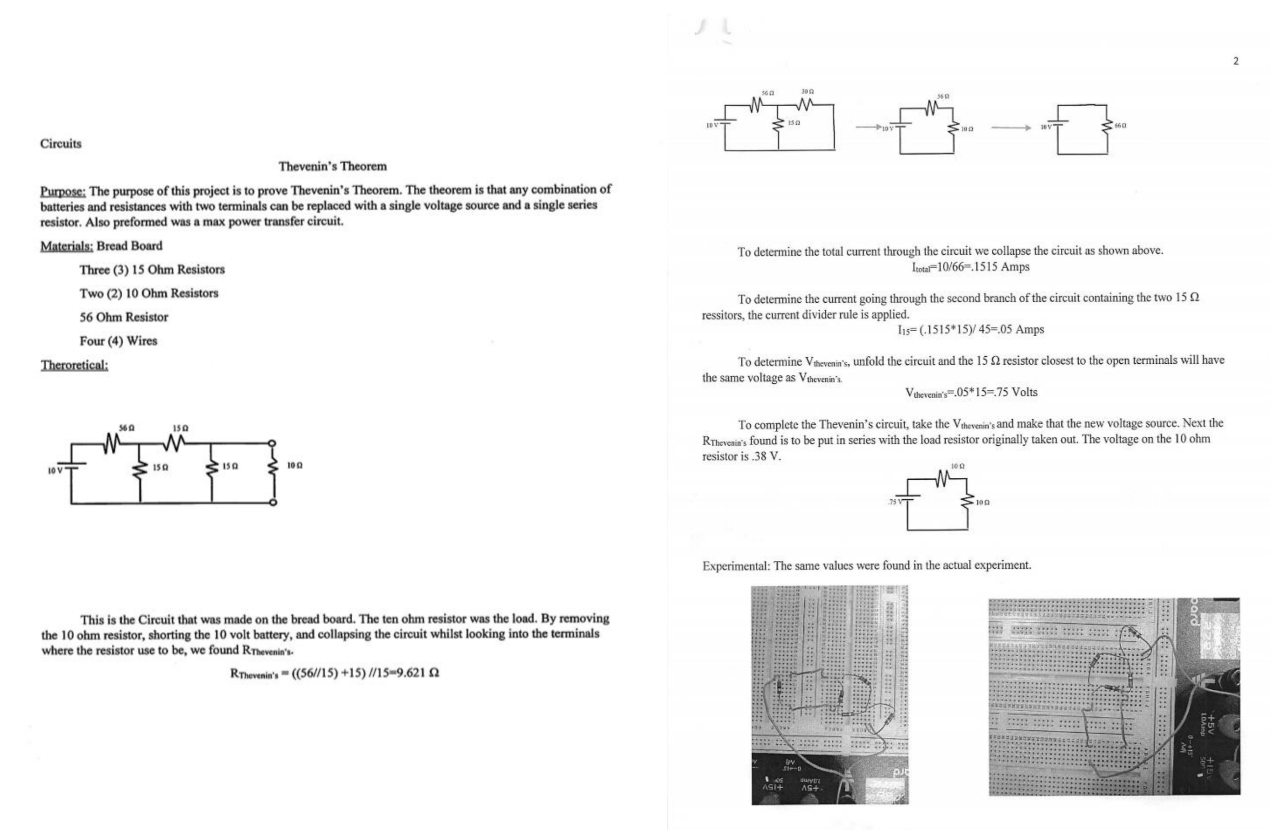
2. The New Practical

Practical Design and Demonstration - 10%

Special Programming - 10%

With all of the effort made in the first semester to give students a background in practical applications it seemed that by the beginning of the sophomore year it was forgotten or at least brushed aside as not being Engineering. When many students in Electrical Engineering classes could not identify resistors or capacitors and did not know what an integrated circuit looked like, it was time to act. As of the fall semester 2014, each syllabus contained one or the other of the above two lines. This meant that students in Linear Circuits I, Digital Logic, Linear Circuits II, Design of Electronic Circuits and a programming course in MatLab, had to conform to the new rule. Students could work in teams of two and with special permission in a team of three. The requirements are quite simple: State what exercise is to be performed. What are the parts and components necessary? Do a sketch of a circuit or a block- diagram. State the theory involved. Get the approval of the Professor. Finish it by the last week of the semester. Demonstrate it to the Professor.

At this point in time the results for the spring semester of 2015 are still outstanding although most of the student groups have committed themselves to the exercise they want to do. As was the case at the end of the previous semester a flurry of activity usually happens in the last two weeks of formal classes. So what were the outcomes for the fall of 2014? Considering the number of groups that participated, one could say that the outcome was positive. They usually boosted their grade by half a letter grade and in several cases would comment that they did not realize what really was behind the theory of a course section and that they learned a lot. The nonparticipants were in most cases students that were close to failing a course and quite often would opt out of Engineering. One thing that was learned that timelines should be tightened up so students will not try to get their projects reviewed in the last two days of the semester.


Circuits

Thevenin's Theorem

Purpose: The purpose of this project is to prove Thevenin's Theorem. The theorem is that any combination of batteries and resistances with two terminals can be replaced with a single voltage source and a single series resistor. Also preformed was a max power transfer circuit.

Materials: Bread Board

Three (3) 15 Ohm Resistors

Two (2) 10 Ohm Resistors

56 Ohm Resistor

Four (4) Wires

Theroretical:

This is the Circuit that was made on the bread board. The ten ohm resistor was the load. By removing the 10 ohm resistor, shorting the 10 volt battery, and collapsing the circuit whilst looking into the terminals where the resistor use to be, we found $R_{Thevenin's}$.

$$R_{Thevenin's} = ((56//15)+15)//15=9.621\ \Omega$$

2

To determine the total current through the circuit we collapse the circuit as shown above.

$$I_{total}=10/66=.1515 \text{ Amps}$$

To determine the current going through the second branch of the circuit containing the two 15 Ω ressitors, the current divider rule is applied.

$$I_{15}= (.1515*15)/45=.05 \text{ Amps}$$

To determine $V_{thevenin's}$, unfold the circuit and the 15 Ω resistor closest to the open terminals will have the same voltage as $V_{thevenin's}$.

$$V_{thevenin's}=.05*15=.75 \text{ Volts}$$

To complete the Thevenin's circuit, take the $V_{thevenin's}$ and make that the new voltage source. Next the $R_{Thevenin's}$ found is to be put in series with the load resistor originally taken out. The voltage on the 10 ohm resistor is .38 V.

Experimental: The same values were found in the actual experiment.

Figure 4. An Example of an exercise utilizing Thevenins Theorem [6]

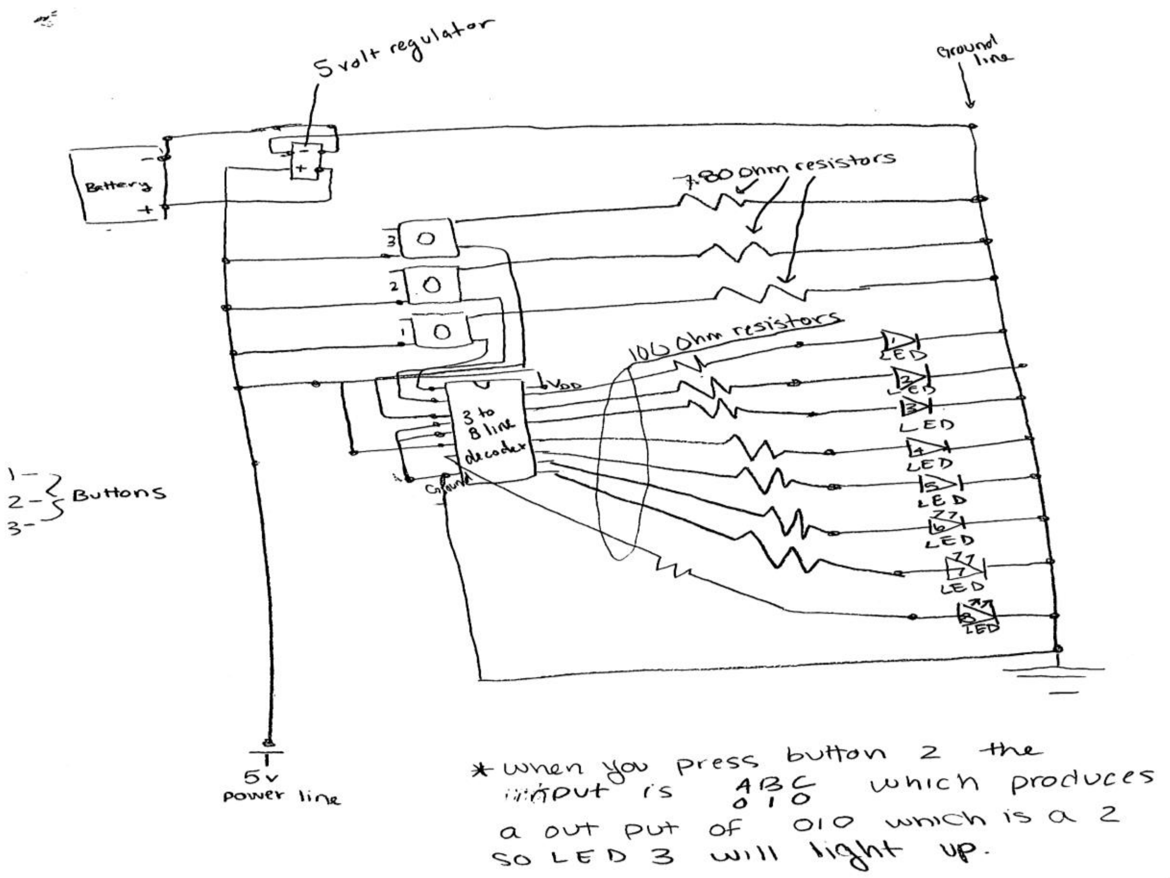


Figure 5. A somewhat rough sketch of a decoder circuit [6]

Figure 4 shows an exercise of proving Thevenins Theorem in Linear Circuits and Systems I. The group of students that used this example commented that they never realized that this Theorem would actually work in a practical application. In Digital Logic class the decoder circuit in Figure 5 was used as a show and tell example. The student group had to buy the Integrated Circuit and use the LED's to show the operation of the circuit.

There were numerous other illustrations of exercises but the above gives a sample of what the general theme of the various projects was.

3. Conclusions

A much clearer picture will evolve after this semesters results are in. So far in the programming course participation is at around eighty percent and in the other courses it is hundred percent. Would students in other Engineering disciplines benefit from a similar type of program? Is the **New Practical** a worthwhile endeavor? A lot of **f**eedback will be needed from students and possibly other faculty members. Observations about this semesters result will definitely have some impact on making future decisions and should be presented at a future conference.

Engineering Technology programs would most likely not have the problems indicated in this paper because most every course has a laboratory attached to it. It is not suggested that Engineering should mimic Technology programs because each has a different mission, but as pointed out in this paper more practicality would not hurt.

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It should be mentioned that if one talks about real engineering problems that students would encounter they certainly would be present in industry. The University of Pittsburgh has a very strong Co-op program and over fifty percent of the Engineering students partake of the program, which starts in the junior year. Students alternate between being at the University for one or two semesters and then rotate into a semester in industry. Here they gain valuable practical experience, make a very good salary and in many cases are hired by the company that they co-op with, after graduation. Student's grades usually improve after being in the program and they mature much quicker due to the responsibility they have shouldered as an engineer in training. [5]

4. Acknowledgement

My wife Celeste as always reviewed the paper for misspelled words, sentence structure and general appearance. Finally, the Faculty Development Committee at UPB if they, as they have done in the past, will partially fund this endeavor, should be thanked.

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Undergraduate Capstone Course for Mechanical Engineering

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Abstract

To bridge the gap between mechanical engineering education and industrial demands, a capstone course, Mechanical Design and Practice, has been offered since the academic year of 1995 to undergraduate students majoring in mechanical engineering. The course aims to cultivate students' creative design abilities and improve their prototyping experience. This course is currently organized as a series of Mechanical Design and Prototyping Projects modules in which junior and senior students apply previously achieved knowledge, skills, and experience to engineering problems. In addition to theoretical analyses, these projects emphasize hands-on practice in mechanical design and prototyping. The current course design is based on almost 20 years of teaching experience and feedback from students and their parents. This paper describes the course design and its rationale. Furthermore, this paper elaborates on the course details and its implementation.

Keywords: *capstone course, mechanical engineering, mechanical design and practice*.

1. Introduction

Engineering graduates constitute the middle- and upper-level workforce in Taiwan's industries. Because product design and manufacturing technologies advance rapidly, product life cycle reduces drastically. Therefore, engineering graduates are expected to have basic knowledge of product design and manufacturing in addition to theoretical analyses, particularly when the industry is facing increasing global competition. Thus, we must modify, improve, or replan the programs offered at schools for helping students become productive engineers.

In the past, engineering education overemphasized theoretical training and neglected cultivating students' creativity and practical experience. In the past decades, students majoring in mechanical engineering (ME) were trained to become mechanical scientists rather than mechanical engineers [1]-[2]. Consequently, such training prevented graduates from applying their accumulated knowledge and experience to industrial challenges, thus making hindering industry growth and global competitiveness. Eventually, students lose their interest in mechanical design and manufacturing, a deviation from the objectives of ME education.

Engineering capstone courses are often an integral part of an ABET accredited program. ABET 2000 Criteria 3 [3] requires that, for an engineering program to be accredited, it must demonstrate that appropriate educational program outcomes are met. Two important educational outcomes required of any engineering program are the ability of engineering graduates to: (1) design a system, component, or a process to meet desired needs within realistic constraints; and (2) design and conduct experiments, as well as analyze and interpret data. A design-build-test concept to train students with above-mentioned skills has been used in undergraduate engineering laboratories and senior capstone design projects [4]-[8].

In our opinion, mechanical engineers should have the knowledge of translating engineering problems and demands into functional, mechanical, and geometrical designs; analysing mechanical properties; selecting and fabricating components; assembling and prototyping; testing, adjusting, and fine-turning; refining and troubleshooting during design and manufacture; and integrating and testing the entire process. This paper discusses the capstone course curriculum, which is based on the aforementioned concept. The Mechanical Design and Practice (MDP) course offered in the past was reorganized as a series of Mechanical Design and Prototyping Projects (MDPP) since the 1995 academic year [9]-[10]. This modified course emphasizes hands-on practical training in mechanical design and prototyping in addition to theoretical analyses training. These on-job training processes are expected to stimulate students' creativity and cumulate related knowledge. Experiencing interchange through industry-supported projects provides students with more practical experience in addition to their theoretical training, which is an objective of the MDPP. Furthermore, students are expected to learn the methodology and attitude of teamwork through these projects.

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2. Current Curriculum Design

Currently, approximately 90 students have enrolled for MDP, and 19 teachers serve as project instructors. The MDPP modules are available in the second semester of the junior year and the first semester of the senior year. The topic of each project and the corresponding instructor are announced approximately six weeks before the beginning of the junior year's second semester. Students are required to form project teams consisting of three members and discuss and clarify the project objectives with their respective instructors. With the approval of the project instructor, the students can select a particular project. Each instructor can instruct no more than two teams.

Although what should be taught to improve students' mechanical design and manufacturing capabilities remains debated, educators and industrial representatives agree that engineering courses must emphasize practical training [11]-[12]; the current MDPP courses are designed accordingly. Besides, the student outcomes requirements by the ABET 2000 Criteria 3 also have been considered in this curriculum design. These two-semester-long courses are designed according to the process of product development and covers concept design, analyses, detail design, prototyping, testing, and modification. Two major concerns exist in designing these courses: teaching and evaluating.

In ME, courses that integrate design, analyses, and manufacturing can help students transition smoothly from the university to the industry, and such courses, which benefit both the students and the industry, must be included in the reorganized teaching program. Therefore, in our two-semester-long MDPP courses, we conduct an hour-long common basic knowledge class with a 10-minute quiz every week during the second semester of the junior year. The contents of this class, listed in Table 1, are arranged in the following sequence: concept design, prototyping, product testing, and modification. All MDPP modules use the same design methodology and approach, which we believe has enhanced students' management and technical capabilities for address engineering design problems. Such capabilities are often not imparted through regular classes despite them being a part of the engineering training. Furthermore, as different processes in mechanical system design and prototyping are similar, the outlines of such modules are similar despite their contents being designed for specific topics. Certain common methods, such as drawing and the use of handbooks and catalogues, are the same for all modules and thus can be taught in the same class. Such an arrangement reduces the instructors' efforts in preparing course material. Teachers for the common course are faculty from our department, the graduate institute of technology management, and librarians.

Table 1. The contents of common topics.

Week	Topic
1	Courses introduction
2	Machine shop safety rule and management
3	Function analysis and creative design
4	How to write report How to do the presentation
5	How to use library resource
6	How to use handbooks and catalogs
7	Project management
8	Introduction to computer aided analysis
9	Drawing technique and standard Tolerances and fitting selection
10	Structure consideration and material selection
11	Power system selection
12	Sensoring and control techniques
13	Tooling and machining
14	Product testing

In both semesters, teams must submit their progress reports to their respective project instructors during the weekly team meetings. In addition, mid-term and final oral presentations are conducted. Guidelines for both semesters' mid-term and final reports are provided to students as a reminder of what should be included in these reports. Moreover, a product exhibition and competition is arranged on a Saturday toward the end of the first semester of the senior year.

The weekly team meetings are jointly conducted by two or three instructors. The weekly progress report must be accompanied by a Power Point presentation, which must be uploaded to the website established for the course. These uploaded files are accessible to all students and instructors. In addition, students can make appointments to discuss projects with their instructors. Students are required to submit weekly work records to their instructors, which are reviewed during the weekly team meetings. For the final product exhibition and competition, an evaluation committee comprised of members from other universities, research institutes, and industries is organized. All teams are required to prepare a 3–5-minute film presenting their projects to the audience. In addition, contestants' parents and the junior, sophomore, and freshman students of our department are invited to visit the exhibition. Moreover, alumni are invited to attend or display their companies' products.

For the evaluation, the grading system is divided into two sections. The first section records the common scoring by all instructors according to each team's weekly report, mid-term and final oral presentations, quizzes, and the final product exhibition. The second section consists of individual scoring by each team's instructor for their respective team(s). The weighting for the common and individual scoring is 60% and 40%, respectively. In addition, the final score for a product is the average of the evaluation committee's and instructors' scores. However, the first three winning teams are selected only on the basis of the evaluation committee's scores. Furthermore, audience votes decide the most popular team in the competition. Scoring guidelines (Table 2) are provided as reference to the instructors, and evaluation guidelines for the final product exhibition and competition are provided to the evaluation committee and instructors (Table 3). A questionnaire (Table 4) is provided to the audience during the exhibition.

Table 2. Scoring guidelines.

Schedule	Guidelines
Mid-term report of the first semester	Motivation, reference analysis, functional specifications, concept design, schedule planning
Final report of the first semester	Performance specifications, detail design, parts drawings, machining drawings, assembly drawings, performance analysis, cost estimation, schedule planning and implementation
Mid-term report of the second semester	Parts/components/modules purchasing or machining, software coding, expense, schedule planning and implementation
Final report of the second semester	Product assembly/testing and modification, completion and differences of performance specifications, expense, schedule planning and implementation

Table 3. Evaluation guidelines for the final product exhibition and competition.

Items	Guidelines
Creativity	originality, practicability, interest
Integration	Planning, organizing and dividing of work, applying and integrating of techniques
Difficulty	Precision, agility, cost, percentage of self-made
Product demonstration	Functionality, performance, appearance, reliability, poster

Table 4. Questionnaire

Number	Question
1	What do you expect to learn from this course?
2	What have you learned from this course and what is the difference with your expectation?
3	What are the biggest gain and the biggest regret for you after taking this course?
4	Do you have any suggestion for course content and practical hands-on prototyping in order to improve this course?
5	Besides above questions, do you have any other opinion that can help future students?

3. Development and Modification

Several modifications and new implementations have been introduced to this curriculum in the past 20 years according to the performance of students and feedback from students, parents, alumni, and teachers. First, the number of team members was reduced to three students mainly on the basis of teachers' experience and student feedback. From our experience, the content and workload of each project is most appropriate for three students working together. This also helps instructors in defining the goal and content for each project. However, we still receive negative student feedback concerning teamwork every year; we have minimized this problem by mandating the weekly work record for tracing every students' performance. Second, all teachers for common topics now consist of faculty from our university rather than industrial engineers and managers, because although the invited engineers and managers have considerable practical experience, they may not be skilled at relating their industrial experience with the basic theories. Moreover, they tend to use complex systems as examples. Students acquire knowledge on several practical industrial methods from the class but are unable to determine how to apply the theories to their design. Therefore, we rearranged the common topics and selected

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appropriate faculty from our university to teach these topics. In addition, the final written examination for these common topics has been changed to a 10-minute quiz for each topic and is conducted at the end of each class for evaluating its effectiveness. In this manner, students can concentrate more on learning each common topic. Third, the two-semester-long MDPP courses, originally offered completely in the junior year, are now conducted in the junior year's second semester and senior year's first semester, because some advanced and supporting courses were conducted for the juniors; thus, students taking the MDPP modules without or while simultaneously applying for the advanced and supporting courses experienced difficulty in theoretical application. This arrangement affords students more time to work on their projects as they have approximately two and a half months of summer vacation between the semesters. Fourth, a weekly team meeting with the team instructor was replaced with a joint team meeting involving two or three instructors. Each team thus receives feedback from instructors with different specializations in addition to other teams. Fifth, the schedule of the product exhibition was shifted from a weekday to a Saturday, thus affording an entire day for the exhibition, which is particularly continent now because of the 27 project teams; moreover, Saturday is more convenient for parents, alumni, students, and members of the evaluation committee. The parents are invited to invigorate student performance and to showcase to parents what their children have learned in past three and a half years in the university. In addition, we provide lunch boxes and refreshments to encourage students who will enroll in this course to attend this activity because this course is mandatory for every student in our department. Sixth, the grading method for each enrolled student has been modified to a weighting system that accounts scores from all course instructors. This change is mainly based on student feedback. Because each instructor has a different grading standard, a final grade assigned only by their respective instructors cannot truly reflect the students' effort. Although this may not be the most satisfactory method of standardizing the evaluation, feedback concerning this problem has decreased after the modification. Seventh, the method of selecting the first three winning teams in the exhibition is judged only by the evaluation committee comprised of external members. However, the grade for final product's exhibition is the average of the evaluation committee's and instructors' scores. This is because the all committee members are external members; thus, their judgement is solely based on the project guidelines and their experience. By contrast, all instructors are internal faculty members who observe these projects from the initial to the final stages; therefore, their judgement is based on a team's effort during the entire year in addition to the guidelines. In other words, committees mainly focus on the outcome of these projects, and instructors focus on both the outcome and the process. Regarding the first three winning teams, we found that the scoring results of the evaluation committee and instructors are always different. In a public competition, outcome is the most crucial achievement evaluation criterion. However, both the outcome and process should be simultaneously considered for student grading. Eighth, to encourage the audience to view all the displayed projects, we provide souvenirs; when the audience votes for the most popular project, they can exchange souvenirs for a lottery ticket. In addition, to encourage the audience to visit all exhibitions, souvenirs are provided to those who receive stamps from over two-third of the exhibitors on specially designed sheets. To achieve a stamp from a project team, an audience member must ask at least two questions about the exhibitor's project. Ninth, two new topics, "project management" and "using library resources," were added to the common topic pool three years earlier according to student feedback. Tenth, the project topic was originally defined by the instructors or the cooperating industries. On the basis of student feedback, some project topics are now defined by students themselves and discussed with instructors to check their feasibility. Thus, the students can design and prototype products they are deeply interested in. The 2014 project topics are listed in Table 5. In addition, we arranged a factory tour two years ago, and student feedback was completely positive. We were unable to arrange a factory tour last year because of the difficulty in finding suitable factories that can cooperate with our schedule. A suitable factory must have machining, assembling, and testing processes in their plant. We will try to arrange factory tours in the future with a more flexible schedule. Figures 1–7 display some of the prototypes accomplished through the MDPP modules in the last twenty years. Figure 8 is a photograph of last year's awarding ceremony of the product exhibition and competition.

Table 5. Project topics for year of 2014.

Team number	Project topic
1	Design and prototyping of fuel-economic vehicle
2	Design and prototyping of picking and shotting robot
3	Design and prototyping of automatic window shutting device
4	Design and prototyping of automatic garbage classification system
5	Design and prototyping of table tennis training device (I)
6	Design and prototyping of bicycling powered cooling system
7	Design and prototyping of car door safely opening system
8	Design and prototyping of foreign object detecting device for chip crusher
9	Design and prototyping of thin woofer
10	Design and prototyping of using 3D printer technology with bio material for manufacturing three dimensional structure frame
11	Design and prototyping of solar powered sea water desalinating system
12	Design and prototyping of glass cutting and splintering device

13	Design and prototyping of measuring device for running friction of telescopic cover of machine tool
14	Design and prototyping of massage device with robotic arm
15	Design and prototyping of automatic vacuum cleaner
16	Design and prototyping of robotic dog
17	Design and prototyping of robotic arm
18	Design and prototyping of shock absorber
19	Design and prototyping of Stirling engine
20	Design and prototyping of caffeine measuring chip
21	Design and prototyping of low speed, fast disassembling coffee bean grinder
22	Design and prototyping of automatic robotic arm with vision detection
23	Design and prototyping of walking stick with automatic support assisting
24	Design and prototyping of table tennis training device (II)
25	Design and prototyping of automatic car parking system
26	Design and prototyping of small wind-driven generator

Figure 1. Glass cutting and splintering device.

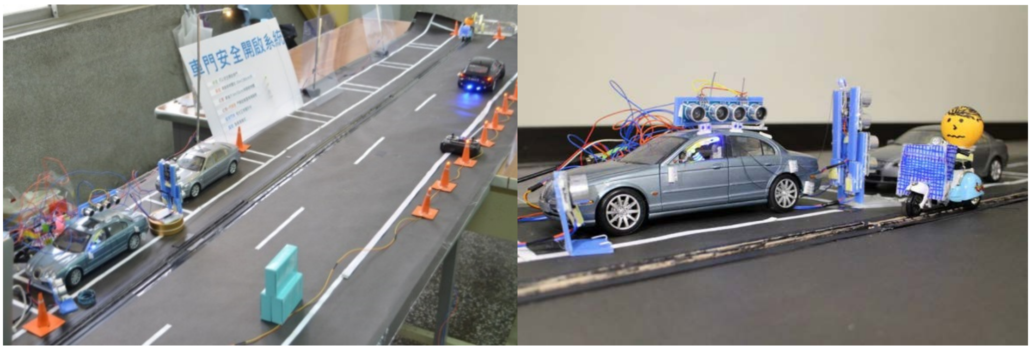

Figure 2. Car door safely opening system.

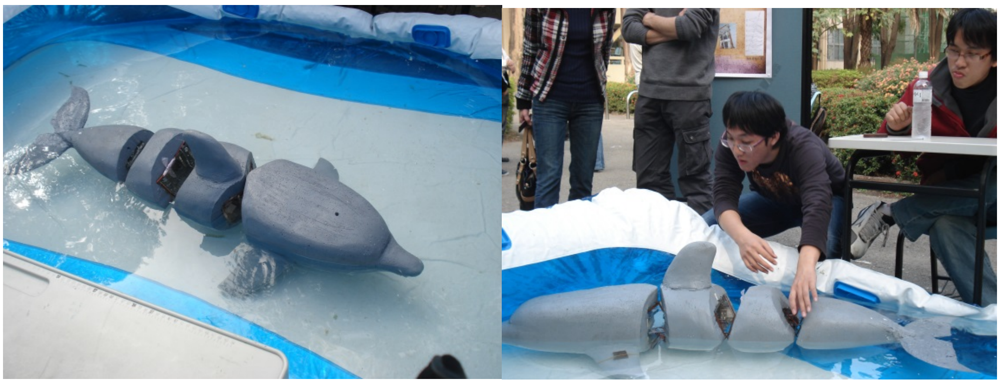

Figure 3. Mechanical dolphin.

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Figure 4. Rock-climbing training equipment.

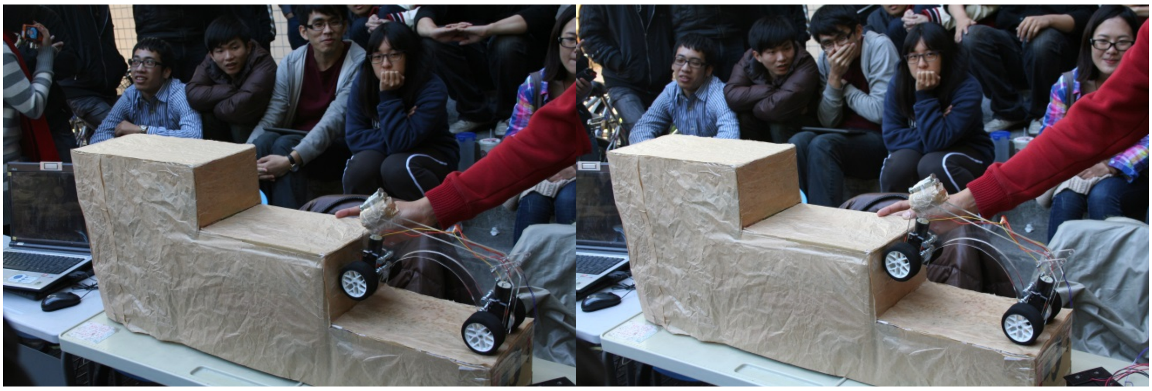

Figure 5. Stair-climbing robot.

Figure 6. fuel-economic vehicle.

Figure 7. Basketball picking and shotting robot.

Figure 8. Awarding ceremony of product exhibition and competition.

4. Conclusion and discussion

In the first MDPP course, attended by approximately 90 students, eight instructors guided eight teams consisting of 10–12 students. Team management in such cases, particularly managing the juniors, was difficult. The project teams were formed at the beginning of the course. Many students were initially not genuinely interested in this course and attended only to fulfil the department’s requirement. After a year of working on their project, their attitude changed because they saw their design materialize. They learnt how to apply the theories, which no longer seemed to be simply equations in textbooks; they realized the practicality of the theories and more comprehensively understood the theories now than they did the studying them theoretically. Crucially, they currently have more confidence in themselves. At present, students show great interest in this class. They form project teams even before the class begins, with most future teams forming after the students attend the current year’s exhibition. Furthermore, at present, 19 faculty members, approximately two-third our faculty strength, teach this course.

Engineering education plays a major role in the society and therefore must be carefully designed to ensure that students learn what is required in the industry. This article describes a series of project-oriented modules intended to provide students majoring in ME a more hands-on experience in manufacturing design and more exploration of the related knowledge in addition to theoretical training.

As the department is located in central Taiwan, the heart of the Taiwanese mechanical industry, we strongly feel responsible for providing the mechanical industry with graduates who skills are close to that required in the industry. Furthermore, we highlight that we are unable to reorganize the course without the right timing and environment. The present course includes several projects supported by the Ministry of Education, industry-supported co-ops and research projects, cooperation with research and development institutes, and the College of Engineering at the National Chung-Hsing University. In the future, we plan to relate the project topics as close as possible to the industrial needs, which can further enhance the course and guide it in the right direction.

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A National Educational Resource Center on Machine Tool Technologies

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Abstract

The machine tool (MT) industry of Taiwan is important as it is ranked the sixth in the world. While there is a long-term and continuous need of engineers in this industry and it is difficult for an institution to cover all fields in MT technologies, this paper describes the development of a nation-wide educational resource center for this purpose. The National Education Resource Center on MT Technologies at National Chung-Hsing University (NCHU ERCMT) is an academy-industry alliance aimed on MT technologies and located at NCHU in Central Taiwan. Members of this center consist of universities, with major efforts in MT related area, across Taiwan as well as industrial companies. Mission of this center includes developing curriculum on MT technologies and shared coursework across institutions as well as organizing nation-wide/international seminars, student project competition and student summer internship. The curriculum includes a series of core and advanced courses, seminars as well as hands-on laboratory courses and field trips. Due to limited industry-experienced faculties in universities, several courses are lectured by senior engineers and managers from near-by MT industry and research institutes. Some others, in particular laboratory courses and field trips, are supported by research institutions and companies through industry-academy alliance. Lectures of core course are broadcasted to classes at partner institutions through network. Seminars in MT technologies, including two to three international seminars each year with invited speakers from overseas, are open to public including near-by industries. A nation-wide student project competition, funded by industry, in MT technologies is held each year that encourages students put more efforts on hands-on practice with knowledge learned from the curriculum. Funding of this competition from industries are over NT$2,000,000 (about US$700,000) per year. Summer internship is also promoted under this center that provides a platform for industry-oriented practical training for students from partner universities. Although this center was originally supported by the Ministry of Education, matching funds and academic-industry cooperated research project from member institutions and industries enriches this educational center to strengthen the relationship between academy and industry.

Keywords: *educational resource center, machine tool technologies, academy-industry alliance, curriculum development, student project competition, summer internship.*

1. Introduction

Machine tool (MT) industry is the “mother of industries” as it is one of the most fundamental industries. In the year 2014, Taiwan’s MT industry ranks the sixth in the world and ranks forth in export. It is particularly important for central Taiwan since more than 75% MT makers in Taiwan are located in this area. While university graduates is the main source of high-level manpowers for the industry, it is difficult to educate students in the field of MTs as it needs extensive training on design, analysis, manufacturing knowledge as well as practical hands-on experience. Normally, graduates in mechanical engineering are to be educated to understand general knowledge about mechanical engineering, while not supposed to be trained to become experts in specified industrial technology. Under this circumstance, it is difficult for most institutions to design a series of courses to cover technologies in MTs. However, it usually takes a new graduate student in mechanical engineering more than one year to learn and to understand fundamental technologies in this industry. Furthermore, most institution’s faculties do not have enough experience in this field to teach these students, no to mention expensive laboratory work. This condition is common in most universities because most faculties stress their research work on high-tech related work but not the so called “conventional” industry. As a result, the gap between the MT industry and academic institutions can not be filled. This leads to the fact that it is very difficult for this industry to recruit machanical engineering graduates in order to upgrade their technologies. The situation has been found in different industries and was noticed by the industry and by the government. It is then suggested to the Ministry of Education (MOE) to improve the condition, in particular to fullfil the gap between the training at academic institutions and the requirements in industry. A task force on engineering education,

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with improving the interactions between the academic institions and industries as one of its missions, was then formed and funded by the MOE [1-2]. The programhas been applied to different industries, including precision machine/mechatronics and aerospace[3-7]. In the past four years, the program was reformed with emphasis on industries, including the MT industry, that are locking of high-level engineers.

2. Structure of the NCHU ERCMT

The “National Education Resource Center on MT Technologies at NCHU” (NCHU ERCMT) is an acedemy-industry alliance, aimmed on high-level engineer traing as well as industry oriented research in MT technologies, is located at National Chung-Hsing University (NCHU) in Central Taiwan. This center was formed by seven universities across Taiwan, four in central Taiwan, two in northen Taiwan and one in sountern Taiwan, with a conjoint vocational high school. As close to the heart of the MT industry, the department of Mechanical Engineering (ME) of NCHU serves as the educational resource center (ERC) and plays an important role to form the team for training colledge/graduate students to meet the need of the MT industry in Taiwan.

As shown in figure 1, the NCHU ERCMT is organized with partner instituions and an academy-industry alliance with an Advisory Board and the Executive Committee. The ERC provide a platform that enhances the communication between academic institutions and industrial members.

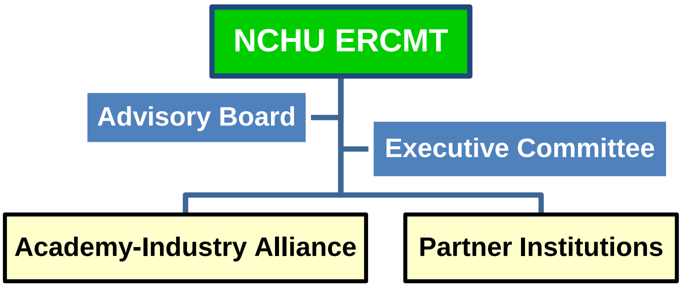

Figure 1. Structure of the NCHU National Educational Center on MT Technologies

The partner institution consists of eight partner institutions, seven universities and one vocational high school listed as the followings: NTU, Chung Yuan Christian University (CYCU), National Chin-Yi University of Technology (NCYUT), National Chunghua University of Education (NCUE), Da-Yeh University (DYU), National Chung Cheng University (NCCU), National Kaohsiung University of Applied Science (NKUAS). The conjoint high school is National Kangshan Agriculture & Industrial Vocational Senior High School (NKAIVSHS) which is connected to NKUAS with a special academy-industry cooperated class. The advisory board consists of representatives from Taiwan Association of Machine Industry (TAMI), Taiwan MT & Accessory Builders’ Association (TMBA), Mechanical Industry & System Research Laboratory (MIRL), Precision Machinery R&D Center (PMC), Metal Industries R&D Center (MIRDC), Hiwin Technology Co., Ltd. (Hiwin), Goodway MT Group (Goodway), Ching Hung Machinery & Electric Industry Co., Ltd (CHMER) and National Taiwan University (NTU). The Executive Committee is formed by representatives from partner institutions so that members of partner institutions can directly dialogue with representatives from industries through this ERCMT platform as shown in figure 2.

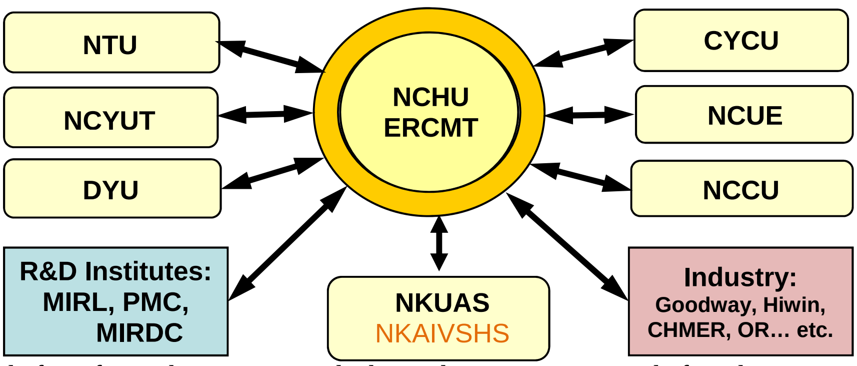

Figure 2. The platform for student training and talent cultivation is consisted of academic units, R&D units as well as industrial units.

The Industrial Alliance is the alliance among these partner institutions, research organizations and industrial companies, including MIRL, PMC, MIRDC, Goodway, Hiwin, CHMER, Victor Taichung Machinery

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Works Co., Ltd. (OR), Chin Fong Machine Industrial Co., Ltd., Yeong Chin Machinery Industries Co., Ltd., The Fair Friend Group, Awea Mechantronic Co., Ltd., Dahlih Machinery Industry Co., Ltd., Kao Fong Machinery Co., Ltd, Kao Ming Machinery Industrial Co., Ltd., Falcon Machine Tools Co. Ltd., Top Work Industry Co., Ltd., Advantech-LNC Technology Co., Ltd., Tongtai Machine & Tool Co., Ltd., The Anderson Group, Chien Wei Precise Technology Co., Ltd., C Sun Manufacturing Ltd., Yida Precision Machinery Co., Ltd. and Chiuan Yan Technology Co., Ltd. etc. Industry-related training such as industrial lectures, hands-on practice, field trip and summer internship can be arranged through this alliance. Courses offered in the NCHU ERCMT also open to members of the alliance.

As previously mentioned, resources, including faculties and facilities, at the university are limited, outsourcing cannot be avoided in this circumstance. Furthermore, as has been observed, industrial collaboration can lead to a better acceptance of college graduates at the job market [8], it is also one of the missions for the ERC to promote industry-academic cooperations. Through the NCHU ERCMT platform, we established the connection with industries and other institutions in curriculum promotion, equipment sharing as well as establishing application-oriented industrial projects. Communication and cooperation with industries and other academic organizations are through this center. Through this platform, several projects was initiated and completed. Through the industry-academic cooperated projects, industries can fully or partially solve their problem, while faculties and students of academic institutions have opportunities to work on real industrial problems. Certain projects also provide chances for students to apply for summer internship to practice in companies during the summer break.

3. Curriculum and Course Design

As described in previous section, the industry-academic educational alliance provides a channel for interaction between the industry and the institution. While most industry-academic cooperation emphasizes on funding research project, such as Liou & Croft [9] and Huang & Ouyang [10], the content of cooperation has recently shifted to be more education-oriented, in particular industry-supported design projects or company-supported equipment and material [11-16]. Due to the limited resources in faculties and facilities in the university, some application-oriented courses in the curriculum are supported by senior engineers and managers from near-by MT industry. Some others, in particular laboratories and field trips, are supported by other research institutions and companies in this area through the industry-academic alliance. This arrangement differs from previous models of industry-academic cooperation project as university faculties and company managers designed topics of the course at the beginning. Senior engineers and managers then provide contents of the courses according to the syllabus.

Table 1. Courses design of the NCHU ERCMT curriculum.

Fundamental Courses (required): Engineering Drawing, Automatic Control, Principles of Mechanical Design
Core Courses: (four tracks) **1. Machine Tool track: (elected, at least 2 courses)** Introduction to Machine Tool Technologies, Introduction to Precision Engineering System, Design and Analysis of Machine Tool System, Metal Cutting Principles, Computer-Aided Design and Manufacturing, Numerically Controller Machine Tool, Precision Machining, Introduction to Micro Machining, Design and Analysis of Machine Tool Controller, CNC Controller and Its Applications **2. System Design track: (elected, at least 1 courses)** Introduction to Engineering Design, Creative Design, Optimal Design, Computer-Aided Design, Computer-Aided Engineering, Intelligent Machine Tool, Multi-Axis Compound Machine Tool Technology, Tolerancing Engineering, Principles of Precision Machine Design, Finite Element Analysis, Engineering Experimental Design and Analysis **3. Mechatronics track: (elected, at least 1 courses)** Introduction to Mechatronics, Applications and Practice of Mechatronics, Electronic Machinery, Motor Control, Digital Control, Digital Signal Process, Signal Process and Analysis, System Identification, Microprocessor and Its Applications, **4. Sensing and Measurement track: (elected, at least 1 courses)** Introduction to Measurement, Principle of Measurement, Precision Measurement Sensor Technologies, Principles and Design and Measurement System, Micro Sensor and Actuator,

Since the focus of this NCHU ERCMT curriculum is on technologies and applications for MT industry, courses in this curriculum, as shown in Table 1, are divided into two levels: the fundamental courses and the core courses. The fundamental courses consist of Engineering Drawing, Automatic Control and Principles of

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Mechanical Design that are required for each students participating in this program. The purpose of core courses is to help students to establish the core knowledge and basic ability in MT field. There are four tracks of the core courses that are the machine tool track, the systems design track, the mechatronics track and the sensing and measurement track. Each track consists of several courses for selection. Courses in each track focus on certain area of knowledge in order to provide students with enough theoretical background in a specified area of technology. Students in this program are required to take one or two courses in each track to ensure their access to different field of technologies employed in the MT industry. Experiments or prototypes are required for some core courses that enable student to familiarize themselves with technology through hands-on practice while studying the theories. In addition to the scheduled courses, a series of seminars focus on the development of precision MTs technologies, opened to general public, is also offered. Individuals not belonging to the member of NCHU ERCMT can take the credit by registering as an auditor.

The courses offered in Table 1 are interdisciplinary and difficult for one department/division to offer all courses, these courses are offered by different laboratories of partner institutions, as shown in Figure 3, or industrial lecturers that participated this ERCMT. Some laboratories specialize on MT technologies while some others are strong in sensing and control technologies and the others are expertise on mechatronics and system integration. With this ERC platform, some common course, such as “Introduction to Machine Tool Technologies” offered by industrial lecturers, are broadcasted to each interested institution through network. With this arrangement, students can plan ahead to register these remote classes.

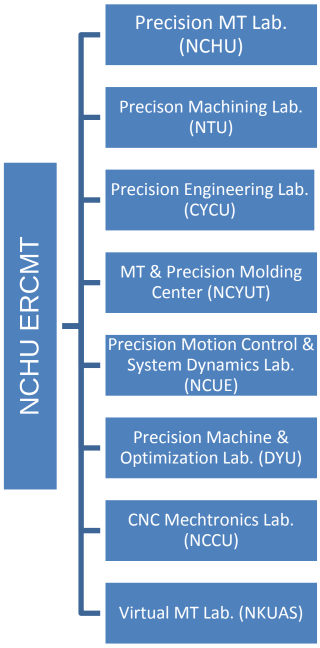

Figure 3. Laboratories of partner institutions participating the NCHU ERCMT.

As an example, the course “Introduction to Machine Tool Technologies” is a basic course for students participating this program. This course involves various aspects of industrial MT and is divided into three units – ‘design of MTs’, ‘machining technologies’, and ‘inspection and testing of MTs’. Each unit is designed by university faculty but organized by near-by MT research institutions, including MIRL, MIRDC and PMC. Each unit consists of a series of three-hour lectures from fundamentals to applications. A field trip with real demonstrations is also arranged by the end of each unit. The contents and organizers of the TPMT course are listed in Table 2. This course gives students a general understanding of design, analysis, and testing of the MTs as well as how theories can be applied to industrial products.

Table 2. Contents and supporting institutions of the course “Introduction to Machine Tool Technologies”

Unit	Lecture	Supporting unit
Design of MTs	Introduction to design of high speed MTs	MIRL
	Design of high speed spindles for MT	
	Design of feeding systems of MTs	
	Design of control systems of MTs	
	Design of ATC systems	
	Field trip: MIRL	
Machining technologies	High speed machining and its MTs	MIRDC and PMC
	New structure of MTs	
	Technology and development of MT control and machining	
	The technology and development of micro-machining	

	Field trip: Mori Seiki/DMG Taiwan	
Inspection and testing of MTs	The relationship between the evolution of MTs and precision measurement	PMC
	The accuracy and inspection of MTs	
	The performance and testing of MTs (1)	
	The performance and testing of MTs (2)	
	Field trip: PMC	

Figure 4 is an example of the course slide that illustrates a motor-built-in spindle designed for a high-speed MT. Students are excited to reach such information on the technology as the spindle delivers much higher power than a dental drill does, though both rotate at high speed. The design of such a spindle needs more extensive considerations and analysis, as its dynamic characteristics are different from a regular one. MT structure for high-speed machining (HSM) is therefore differs from a common one in order to meet these higher specifications required for HSM. AT the right of figure 4, it shows another slide used at one of the lectures in the course to describe different machining processes. Some other machining processes are also demonstrated at the lecture. Students learned from this lecture that conventional machining processes could provide good accuracy and tolerancing, as compared to these so called 'high-tech' miniaturized fabrication processes. This is an importance issue as the job in MT industry is not very attractive to students because graduate students are often attracted by the 'high-tech' industry.

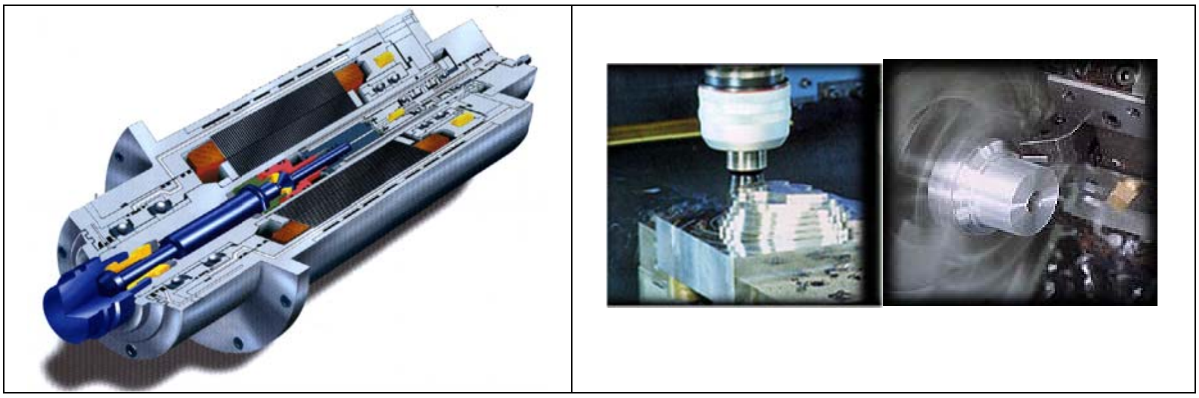

Figure 4. Examples of course material showing the design of a MT spindle and applications on different machining processes.

4. Progress and Achievement

In addition to Curriculum, one of the important missions of the NCHU ERCMT is to incubating seeding lecturers for partner institutions and provides hands-on practices for them and students. Figure 5 (a) is a snap of a training camp dedicated for seeding lectures from different universities, in particular from the partner institutions. Figure 5(b) shows a lecture by an industrial engineer who presents realistic industrial examples at the lecture. Figure 5 (c) is a seminar given by an invited international speaker. Figure 6 shows a few examples of hands-on practice of a training camp for seeding lectures. These seeding lectures needs more practice as they have to teach students once they return to their institution. On the other hand, figure 7 shows some examples of student hands-on practice at laboratory and field trips to companies. Students obtains realistic experience and feeling from these activities.

(a) (b) (c)

Figure 5. Examples of lectures: (a) training camp for seeding lectures from different universities; (b) lectures by industrial engineers; and (c) speakers at international seminars.

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Figure 6. Examples of hands-on practice of training camp for seeding lectures from different universities

Figure 7. Examples of student laboratory hands-on practice and field trip to industries

In the year of 2014, the NCHU ERCMT has achieved its goal of missions. These missions, as shown in Table 3, include (1) Enhancing fundamental learning environment, (2) Integrating and sharing educational resource, (3) Establishing Academy-industry-Research educational platform, and (4) Holding a nation-wide Competition of Student Project. Each mission item further consists of many activities achieved by partner institutions. A special event achieved by the NCHU ERCMT is holding two nation-wide competition and exhibitions of student projects, including student capstone projects. One competition is the “Goodway Nation-Wide Competition on MT Technologies” and the other one is “Chiuan Yan Cross-Strait Competition on Motion Technologies”. The first one is supported by the Goodway Group, a member of the NCHU RECMT, that emphasis on the design and prototying of MT-related technologies, including new configuration/mechanism of MT, sensing/control, mechatronic, and precision measurement. The competition provides both graduate and undergraduate levels and takes six months for each team to start from conceptual design, detailed design, fabrication and testing. The Goodway Group donated more than NT$1,200,000 each year for awards and consumable material for this activities. The latter is a competition of student project/paper for student teams from either Taiwan or China. It is funded by the Chiuan Yan Technology Co., Ltd. (A&F), another member of the NCHU ERCMT, which produce motion stage/component. A&F donated NT$800,000 each year for this activities. This special activity, two nation-wide student project competitions sponsored by industrial companies, differs from other ERCs sponsored by the MOE. This is an effort by the members of the NCHU ERCMT. Both companies are committed to sponsor the two competitions in the following years and another company already committed to sponsor another nation-wide competition on spindle technologies starting from 2015.

Table 3. Achievement of the NCHU ERCMT in 2014.

Item	Activity	Quantity
Enhancing fundamental learning environment	Design and offer of professional courses	10 courses
	Strengthen featured laboratories	8 laboratories
	Seminar and training courses	8 seminars/ courses
	International interactions/ inviting international professionals to deliver talks at international seminars	8 international speakers
Integrating and sharing educational resource	Design and editing feature courseworks	5 courseworks
	Promotion of MT curriculum and feature courses	1 curriculum
	Remote education (broadcasting)	2 courses
Establishing Academy-industry-Research educational platform	Academy-Industry Cooperative teaching	110 hours
	Industry field trips and summer internship	field trips: 200 summer internship: 320
	Special topics by industrial lecturers	16 lectures
	Academy-industry co-operative projects	16 projects
	Hands-on practice of faculties of partner institutions	10 faculty members

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Nation-wide Competition of Student Project	Competition of student projects (both graduate and undergraduate levels)	2 (with donation NT$2,000,000 from two cooperative company)

5. Conclusion

As MT technology is one of the most important technologies for industry, incubation and training of high-level engineering manpower in this field is a critical issue. This paper describes an effor to establish a nation-wide educational resource center, the NCHU ERCMT, with an academy-industry alliance. The mission of this center includes (1) Enhancing fundamental learning environment, (2) Integrating and sharing educational resource, (3) Establishing Academy-industry-Research educational platform, and (4) Holding Nation-Wide Competition of Student Project. While many activities are achieved of each mission item, this paper addresses the structure and the ERC, the design and contents of the cirriculm and achievemnets and on-going activities of this center. The mechanism for application course and hands-on practice as well as field trips offered by industrial lectures are also addressed. A special effort of this ERC to hold two nation-wide competitions of MT-related technologies each year is also described.

It has been observed in the past years that both students and industries appreciate the NCHU ERCMT academy-industry alliance as students lean much more industry-oriented engineering practice while industry can recruit students with better background they need. Some application-oriented industry-supported courses also show a success as the enrollment keeps high in these classes. A new trial of a course designed by faculties and industrial magagers while organized and lectured by senior engineers and managers from nearby industrial also showed a success. It is found that students are satisfied and feel comfortable for such arrangement as they learned much more than before through industry-supported technical lectures and field trips. It is also observed that the strategy is successful to arrange industry-oriented application courses and seminars via the academy-industry alliance.

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An International Action for Cooperation in Engineering Education between Spain and Morocco

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Abstract

The University of Burgos in Spain has launched, since 2012, an institutional development cooperation for education programme which involves three types of actions. First, staff interested in driving academic research and studies in this field. Second, students interested in developing their final degree-work in developing countries, with the help of some NGO. And third, to staff with the aim of developing institutional training programmes with higher education institutions in developing countries. This paper presents a case study of the cooperation for education programme developed between two faculties of engineering in Burgos and Morocco between 2011 and 2015. Results in terms of activities developed, participants and institutional issues are presented. The relation between research and education will be highlighted as a key factor to carry on such cooperation action. Challenges and pitfalls of the exchange of students and lecturers for learning purposes, teaching courses on engineering education innovative methods to staff and mutual benefits for future research and cooperation for education are described. The experience has produced a multiplicative factor as new opportunities for cooperation have appeared.

Keywords: *International Cooperation, Developing Countries, Long-life Learning.*

1. Introduction

International cooperation in education is becoming increasingly important and prevalent. A characteristic feature of the exchange of people and ideas at the start of the 21st century is the fact that these processes take place at various levels. Concerning the cooperation programmes for developing countries, they focus primarily on providing continuing education and training for young academic staff. With the rise of globalization, institutions of higher education need to become more international in order to operate effectively in the global education market [1]. This also calls for more student and scientist exchanges. As a result, international exchange has become an even more important requirement for modern universities, top-quality research and innovation. Nowadays many universities have promoted international cooperation for education programmes addressed to developing countries, with the objective of offering to students and staff interested an opportunity for transferring knowledge and experience to developing countries [2], [3]. Frequently, engineering education institutions are also concerned by this approach [4], [5].

As described in [6], two main types of funding programmes have been around for quite a number of years: a) programmes which fund collaborative projects between organisations in developing countries and higher education and research organisations in the North, and b) fellowship/scholarship programmes that enable candidates from developing countries to obtain a diploma or degree abroad. While the fellowship programmes predominantly focus on capacity building for the individual, the collaborative programmes tend to focus on strengthening an organisation’s performance capacity. The common objectives of higher education cooperation programmes within the framework of development cooperation are capacity building (teaching, research and outreach), organisational and/or institutional development, research collaboration, and networking between Southern and Northern partners. These objectives tend to overlap. In many higher education cooperation programmes, two or three of these objectives are combined. Capacity building may well form part of the organisational strengthening process, and capacity building and organisational strengthening may have to be in place on the Southern side before research collaboration between partners can begin.

The University of Burgos in Spain has launched, since 2012, an institutional cooperation for development and education programme which involves three types of actions. First, staff interested in driving academic research and studies in this field. Second, students interested in developing their final degree-work in developing

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countries, with the help of some NGO. And third, to staff with the aim of developing institutional training programmes with higher education institutions in developing countries. This paper presents a case study of the cooperation for education programme developed between faculties of engineering in Burgos and Morocco.

2. The development cooperation for education program of the University of Burgos

The University of Burgos took in 2008 the initiative of broadening the International Relations Service, devoted to manage international activities for educational purposes (Erasmus, specific agreement for incoming foreign students, etc.) to an International and Cooperation for Development Service. The aim was to extent the international activities to developing countries where our University could act as a donor. At that moment, there was a demand for such actions coming from some university associations and university staff belonging to NGOs. During the period 2008-2012 actions were carried out by individuals and launching the first institutional program. Since 2012, the institutional program was consolidated, even the decrease of budget due to the general economic crisis come to Spain since 2009. At present, the main lines of cooperation for development actions could be divided in three types [7]:

1. Grants for students.
   Students that will develop their final diploma work (Bachelor, Master, Practicum, ...) in developing countries. Frequently collaboration with NGOs was required a s a mean of finding the country and the precise location and task to develop. Since 2003, more than 30 agreements between the University of Burgos and NGOs were signed to allow participation of students and staff in cooperation activities as volunteers.

2. Grants for staff.
   Staff who aim to develop cooperation for development projects *in situ*. The participation of staff as tutor of students participating in the previous action is concerned, but also the staff developing training or innovative actions to help higher education institutions or educational schools to improve its capacities.

A specific case of cooperation is the project UBU-Bangalore, which is a long-term action of the University that has involved many teachers and students along the period 2009-2014. UBU-Bangalore [8] is an association linked to the University of Burgos with the objective of development of several projects in South India, more precisely in the city of Bangalore, where several teachers and students go to work with homeless children one month per year.

3. The case study of the cooperation for education and research program developed between faculties of engineering in Burgos and Morocco.

The energy engineering group of the University of Burgos is constituted by 8 members, amongst them senior professors, lecturers and young researchers. The research activities are related to energy efficiency and properties of new fluids and materials of low environmental impact, such as biofuels, new refrigerants, phase change materials for energy storage and enhanced heat transfer liquids. From the side of educational innovation, the team performs some research on teamwork skill, or active and cooperative learning teaching methods, as a way of improving their teaching in energy topics such as Engineering Thermodynamics, Theory of Circuits, Heat Transfer, Energy Technology, Heat Engines or Electrical Installations within the frame of Bachelor and Master courses [9]-[12].

Cooperation for development of our team with Moroccan universities started in 2007 by means of a research internship given to a doctorate student. This was the starting point of collaboration with Moroccan universities that become deeper and wider along the years. Morocco is considered a developing country by the United Nations [13], showing a *human development index* placed in position 129 of a total of 187 countries in 2013, as presented in Table 1.

Table 1. Human development data for Morocco in 2013 following [11].

Human development index HDI	0.617
Qualification	Medium
Relative position	129/187 Third quarter

Collaboration broaden to research stays for post-doctoral researchers, participation in doctoral boards, exchange of undergraduate students, training actions for lecturers, participation in research networks and projects and co-direction of doctorate students, besides the signing of framework agreements between the University of Burgos and some Moroccan universities. Table 2 shows a summary of the actions developed.

Table 2. Summary of development cooperation activities between the Energy Engineering group of the University of Burgos and Moroccan Universities.

University	Type of action	Year	Items	Description
University Abdelmalek Essâadi, Tetouan	Doctoral Board	2011	1	Board of Ph.D.
	Research Project	2011-2013	1	Spanish Ministry of Foreign Affairs and Cooperation Spanish Agency for International Cooperation and Development, Project AP/041072/11
	Post-doctoral research stays	2011	1	3 months Funded by the University of Burgos Staff mobility program
		2013	1	3 months Funded by the Spanish Ministry of Science and Research Project ENE2009-14644-C02-02
	Research articles	2014	1	Indexed Journal Citation Reports, Q1
		2015	2	Indexed Journal Citation Reports, Q1
	International Conferences	2012	3	Research conferences
		2013	3	Research conferences
		2015	2	Research conferences
	Co-direction of doctorate student	2015	1	In progress
University Chouaïb Doukkali, El Jadida	Exchange of undergraduate students	2014	2	1 month Agreement Ecole Nationale des Sciences Appliquées El Jadida / Escuela Politécnica Superior de Burgos
		2015	2	1 month Agreement Ecole Nationale des Sciences Appliquées El Jadida / Escuela olitécnica Superior de Burgos
	Research Project	2015	1	Application to ERANET-MED call, FP7 EU
	Research articles	2013	1	Educational article
		2014	2	Indexed Journal Citation Reports, Q1
		2015	2	Indexed Journal Citation Reports, Q1
	International Conferences	2014	3	1 Educational conference 2 Research conference
		2015	5	1 Educational conference 4 Research conferences
	Staff training on engineering education	2014	1	Course on problem based learning in engineering courses. 14 attendants, lecturers with the Ecole Nationale des Sciences Appliquées El Jadida Funded by the University of Burgos Cooperation for Development program
	Undergraduate courses on engineering topics	2014	2	1 course on electrical safety and chemical laboratories safety. 1 course on energy efficiency in buildings. 40 attendants, students Ecole Nationale des Sciences Appliquées El Jadida Funded by the University of Burgos Cooperation for Development program

From close observation of Table 2, it can be seen that research and educational activities are very intimately connected, in the sense that some research activities had led to educational activities and also the opposite. For example, the research collaboration along the shared project with the University Abdelmalek Essâadi – Tetouan

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in 2011-2013 has led to co-direction of a doctorate student in 2015. In the opposite, the staff training action developed in 2014 by the Spanish lecturers at the Ecole Nationale des Sciences Appliquées El Jadida has led to subsequent meetings to explore future opportunities to collaborate, that have come to an end with the application for an international project within the FP7 research program of the European Unión in 2015. Then research and educational cooperation actions feed each other leading to a multiplicative effect. Figure 1 shows the lecturers and students of the Ecole Nationale des Sciences Appliquées El Jadida with the Spanish lecturers at the end of the cooperation action in 2014.

(a)

(b)

Figure 1. Staff training and undergraduate course at the Ecole Nationale des Sciences Appliquées El Jadida, 2014. (a) Training of lecturers; (b) Students.

Two factors could be pointed out as critical factors to the success of the described cooperation for development actions. First, the institutional support of the University. As stated in section 2, the University of Burgos promotes, through its International and Cooperation for Development Service, the participation of staff and students in international cooperation activities. Even the budget available is quite low the initiative has boosted the number of activities performed abroad by students, teachers and staff along the last 4 years. Besides, the University strongly supports any international research activity of his research groups through its Vice-Rector of Research. Moreover, once any initiative is known, the signature of framework agreements between universities are strongly recommended before any activity is started. These agreements give legal cover to any research or educational exchange, and allow the Head of Faculties and Departments to develop correctly the actions. The University of Burgos signed the agreements with the University Abdelmalek Essâadi – Tetouan and the University Chouaïb Doukkali - El Jadida in 2012 and 2014 respectively.

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The second factor is the need of leading persons in the respective universities. As an example, we point out here that, apart the two aforementioned general agreements with University Abdelmalek Essâadi – Tetouan and the University Chouaïb Doukkali - El Jadida, the University of Burgos also signed another agreement with a third Moroccan University in 2013. However, it became a useless initiative as we did not get any answer to our proposals, which were of the same type and concerns as the proposed to the other two universities. The mutual knowledge and confidence-building of the partners plays the critical role to boost cooperation for development actions. As most funding comes usually from the developed countries, some additional responsibility falls on the side of the proponent university.

Future actions are expected for next coming years. New research and educational activities are underway. Even last 5 years of economic and social crisis in Spain have led to sudden decrease of the national Cooperation for Development funding programs, some other opportunities have appeared at the European Union. Most important, the Spanish and Moroccan universities have invested part of their respective budgets to finance cooperation for development actions in the belief that these activities are also within their social and objectives.

6. Conclusion

This paper presents a case study of the cooperation for education and research program developed between faculties of engineering at the University of Burgos, Spain, and Morocco. Cooperation for development activities have been performed by the energy engineering group of the University of Burgos between 2011 and 2015. Two factors could be pointed out as critical factors to the success of the described cooperation for development actions. First, the institutional support of the University. Second, the need of leading persons within the respective universities. The mutual knowledge and confidence-building of the partners plays the critical role to boost cooperation for development actions.

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Pinpointing Core Competence and Mindset Need in Modern Engineering Studies

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Abstract

The main target in the engineering education can be divided into two different and distinctive areas. The first one covers specific skills and knowledge concerning issues which can be identified as core competence such as skills to calculate the strengths of materials, dimension pumps or write code with some computer programme. The other one is covering a person´s way of thinking, a way of handling social situations and changes in life or needs to update his/her core competence. This latter competence is called usually a social competence but this article prefers term mindset when discussing that competence as a whole.

In the fast changing world it has become obvious that the old way to update curricula and determine graduates' core competence is obsolete. Students who are now starting their studies cannot know whether some skills are needed at all after four or five years, not to even mention the later period of the career, after 40 plus some years. In the middle of the inevitable and continuous change, curricula should be also designed so that they enable an evolutionary approach to instant corrections and adjustments. In addition to the updated core competence, curricula should reflect and strengthen graduates' needs to achieve and use such mindset that is needed in a changing world.

This paper highlights the need of better understanding about competence and skills taken account in the modern engineering education and, in general, nature of the prevailing idea of the core competence and mindset related to the engineering profession is discussed. We argue that up-to-date understanding for the core competence of today and long-term work in building engineering mindset for students are essential keys to the regenerative engineering education. It seems to be that the more diversified the competence requirements are getting, the more freedom should there be included within the frame given in curricula – without losing sight of the overall, field-specific basic competence requirements. Part of the data handled in this paper is gathered from the database of a labor job announcement service of the Finnish Ministry of Labor from the year 2013.

Keywords: *Engineering mindset, Core competence in engineering, Regenerative curriculum*

1. Introduction

Concept of time is not easy to handle. When stated that time is a fourth dimension of space and that changes in it are irreversible, it can be said that *"physical time exists only as a stream of change"* [1]. Change in general is inevitable, dynamic, irreversible, non-deterministic, non-linear, open-ended and continuous [2]. But time is also a unique resource that cannot be stored, it is perishable, irreplaceable and it has no substitute. Demand does not affect it and it has no price or marginal utility curve. One thing above all, when talking about time in modern working life, there is typically some shortage of supply, i.e. we are mostly lacking it [3]; [4]. Principles of constant change and tendency of lacking time are dominating also reality of the companies and societies as well as educational objectives of the universities. For instance, new ideas and more output has to be created in perpetually shortening periods of time.

Enterprises can make new products and services by utilizing the knowhow of several individuals and outsourcing more input to work which means that there is no upper limit for input. On the contrary, there is a maximum limit how much different work and courses can be included in the university degree. In Finland, a curriculum of the Bachelors´ degree in engineering at the Universities of Applied Sciences (UAS) consists of 240 ECTs (1 ETC = 27 hours of work), which means 4 years full time studying. As the main goal of a modern engineering

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curriculum is to make individuals learn, there is not so much to be outsourced in it. Nevertheless, neither universities nor enterprises are excluded from the incessant elapsing of time. First, it is more a question about how effective time usage is and second, how efficiently it is actually used. Since learning should have some effect in acknowledge structure of the students and must be tied to a person [5], his/her way to think and act [6] - or more preferably: to build mindset - term effective is preferred in this article. Efficient time usage is only showing how much time is used to achieve something, the results or gains compared time usage, and not at all whether the results or gains were needed in the first place. Therefore UASs should judge carefully where and how they steer the students to use their time.

Skills and knowledge are in many cases divided into core competences and social competences. As social competences are included in emotional intelligence [7] , some emotional intelligence has to be included into an engineering mindset as well. For this purpose, TUAS is using innovation pedagogy approach where social and interactive skills, cultural abilities, understanding the prerequisites for working in contact with customers, entrepreneurship, creativity, problem-solving skills, tolerance to difference and uncertainty are also hoisted to the core [8]; [9].

Competence requirements for graduating engineers are defined by different ways. National regulation, regional requirements, demands of different fields of industries, interests of lobbying organizations, university professors and teachers for example are giving facets to this multidimensional issue. There are no simple solutions to rank these point of views and decide which one of them should be preferred and which one neglected. I.e., competences cannot be set under bivalent logic “true” or “false”. Common threat for all stakeholders is a phenomenon called WYSIATI: “What you see is all there is”, a phenomenon firstly introduced by economist and psychologist Daniel Kahneman. WYSIATI means that people are usually blind towards unknown or better yet “unknown unknown” and emphasize too many issues which are already visible to them. Visible issues might be issues which are core issues to their work or premises. Over emphasizing visible issues (biased sampling error) in many cases is caused by lack of base rate i.e. relevant reference point [10].

Curricula work is also traditionally very detailed planning work and therefore prone to planning fallacy and illusion of control. No doubt, we cannot control world even if our curricula are planned very carefully. Biases can be very disastrous in the world where plain luck, or probabilities of improbable occurrences - black swans, are more than certain to occur in longer periods of time [11]; [12]. Because of the nature of social science, we cannot say for sure whether some choices will be better than other ones. As a matter of fact, even retrospective scrutiny cannot certify whether choices made were wrong or right. There are too many variables involved to find exact answers whether a curriculum is acting for the better or worse. Classic example could be a question whether Roosevelt´s leadership prolonged or shortened the great depression, which is still under discussion [13].

A curriculum could also be seen as something to trigger the Lucas critique type chain of reaction, where a forecast will create information to make changes for the situation i.e. prevent or rule out some effect or make something possible [14]. This can be possible, but when scrutinizing the effects of a curriculum in general, the conclusions should not be made under narrative fallacy. Especially in any narrative discipline, the explanations are easy to fit retrospectively [15]; [16]. This paper will widen the perspective for curricula planning.

2. Research setting

The research data is received from job advertisements set into the public employment and business services data base of the Finnish Ministry of Labor and from two private job agency systems called Monster and Uratie. The data is mined automatically from the adverts via specific data mining tool which is developed in the South-West Finland´s Center for Economic development, Transport and the Environment. The application collects data from profession-related capability requirements in the job advertisements. The application collects also frequency of different requirements inside an occupation as well as location information. It uses a word search as logic of collecting the data.

The handled job adverts are individual so that duplicates are avoided as much as possible. Some remark is to be set; e.g., there is a chance that some open position is given to more than one recruiting institution. This can mean that each of those three recruiting institutions has made an advert of its own regarding the same position. These kinds of duplicates are not excluded since it is impossible to recognize such a case automatically. With the exception mentioned above, research embodies 18 475 individual job advertisements. Advertisements are set into the data systems between September 2011 and December 2013. Another remark to be set here is the fact that some advertisements may not have been recorded in the first few months, but these are only few exceptions. Population under scrutiny is not manipulated any other way by researchers, i.e. any exclusions are not made.

Job adverts are classified by using the Finland´s official national Classification of Occupations 2001 system. This system is based on the EU´s classification of occupations ISCO-88(COM). This means that every profession is included into some subgroup. Classification system works so that the first digit implies larger group and next digits implies subgroups. These subgroups are divided yet again subgroups by the next digit and so forth to five digits maximum. Research is made so that three first digits are exploited. Figure 1 below here illustrates the main principle of the classification system.

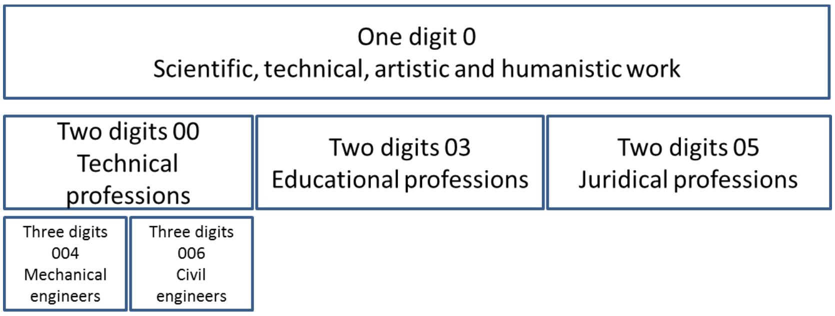

Figure 1. Example of a classification system.

Illustration in figure1 shows only some examples of classification used in the system. Naturally there are more classes than shown in the picture. Though all studied engineering branches are under 00 digits in this system.

Amount of adverts in each of the occupation classes studied here are:

1. automation electronics and ICT (3 138 adverts)
2. chemistry (732 adverts)
3. construction (5 002 adverts)
4. electrical (2 342 adverts)
5. measuring (538 adverts)
6. mechanical (4 635 adverts)
7. other engineering occupations (2 088 adverts)

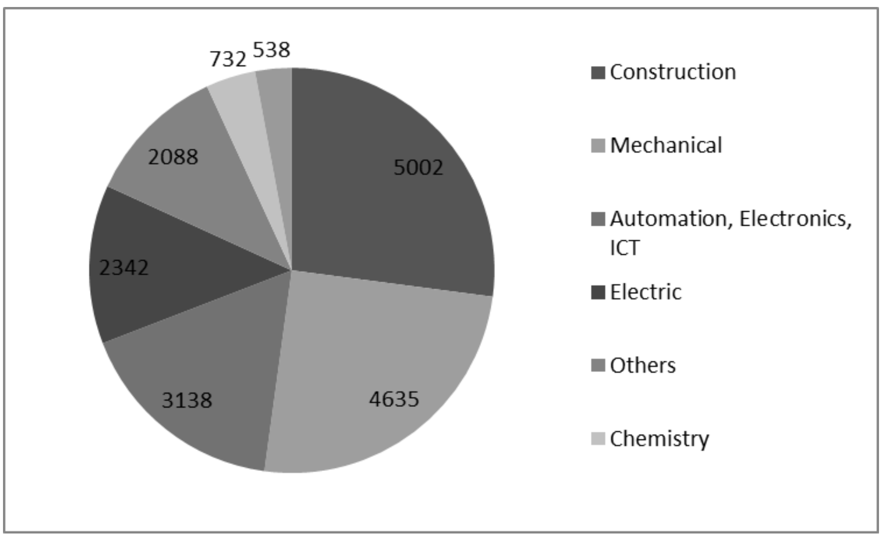

Figure 2. Amount and division of job advertisements. (Altogether 18 475 adverts.)

In figure 2 the amount of adverts in each of the occupation class studied is given with graphics. Adverts cover both Bachelor and Master degree levels. Every occupation class is data mined so that words in a job advert are identified and set under the core competence or social competence/feature. This research handles 15 most wanted core competences and 10 most wanted social competences per occupation class. In that way, the handled data consist of 17 top-ranked core competences and 14 social competences.

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Figure 3 below is generated in a manner that some adjectives or features are gathered under larger schematic themes. Design and engineering category includes definitions such as “engineering tasks”, “design tasks”, “structural design”, ”process engineering”, “automation design” etc. Project category includes definitions like “project management”, “project work” and “project planning”. Quality/control category includes definitions like ”quality tasks”, “controlling”, “testing” and “certification”. Profession specific includes definitions such as: “HVAC”, “real estate techniques”, “SQL-skills”, “land-use planning” etc.

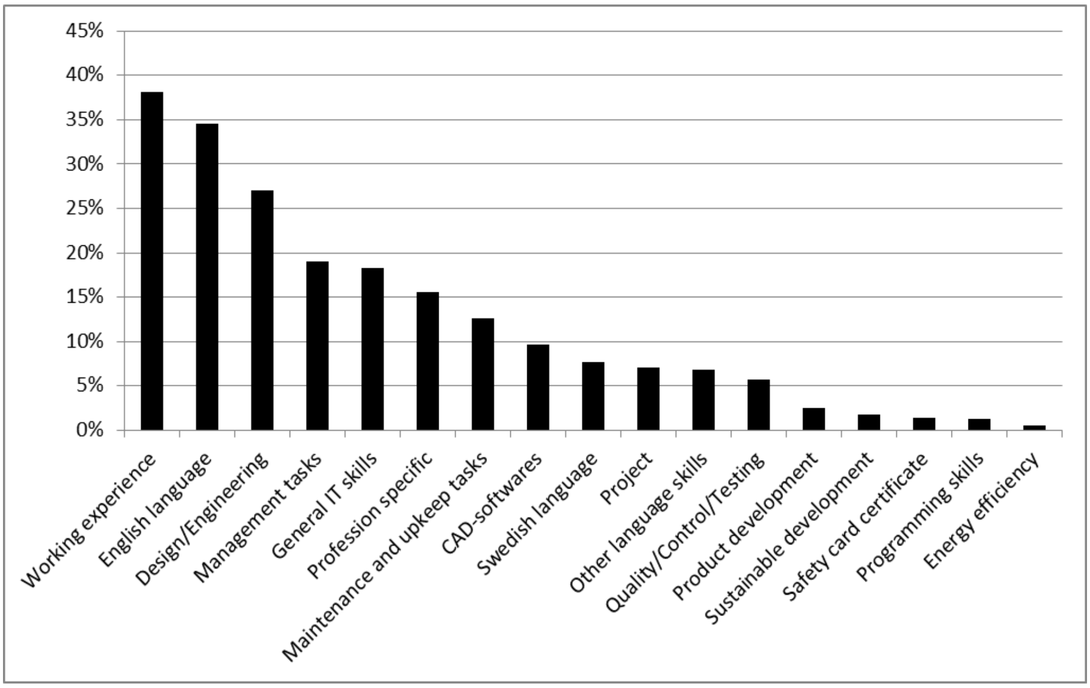

Figure 3. Combined 15 top-ranked core competences.

As figure 3 illustrates, there are three most desired features for engineering professionals: work experience, English language and design/engineering skills. All of these features were mentioned in over 25 % of the job advertisements. Work experience and English language were remarkably higher than others. (Work experience 38,1 %, English 34,6 %). Next group can be formed from management tasks (19,0 %), general IT skills (18,3 %), and profession specific features (15,6 %). These features were mentioned in over 15 % of all work advertisements. Maintenance and upkeep tasks were second of most searched professional knowledge areas after design and engineering (27,1 %) with its 12,6 % share. Almost in every tenth (9,6 %) advertisement CAD-software skills were required. Swedish language skills (7,6 %), project skills (7,1 %), other language skills (6,8 %) and quality and control (5,7 %) were mentioned in more than every twentieth advertisement. Product development (2,5 %), sustainable development (1,8 %), safety card certificate (1,4 %), programming skills (1,3 %) and energy efficiency (0,5 %) also came into the top 15 list of the core competences.

It is remarkable that language skills are highly valued among the engineering job adverts. English language was 2nd (34,6 %), Swedish language was 9th (7,6 %) and other language skills 11th (7 %). Other language skills were usually mentioned such way that “other languages will give you advantage in applying”. Also remarkable is that no other single language was highlighted than English and Swedish. This is probably quite a Finnish phenomenon. Since the language skills are highlighted so much, it must be stated that engineers should possess communication capability at least with one foreign language - preferably more. Therefore the language skills should be included into the core competence.

Figure 4 below illustrates a division of the social competence in job advertisements.

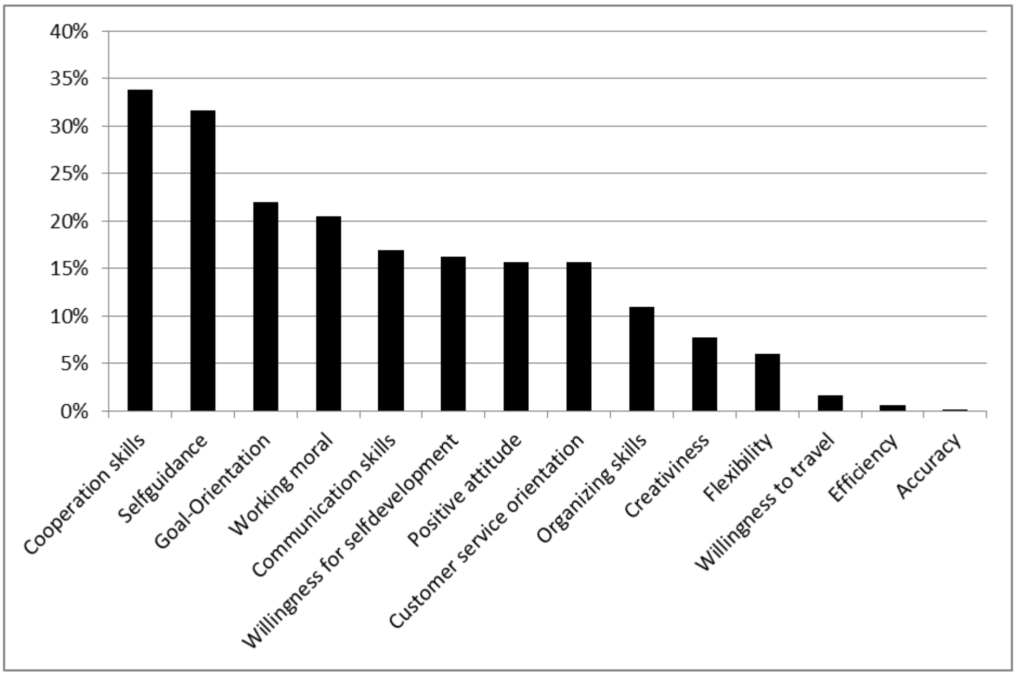

Figure 4. Combined top ten list of the social competence.

It can be seen from figure 4 that two social competences are prevailing quite clearly in the job advertisements of engineering areas: cooperation skills and self guidance were mentioned in every third job advertisement as shares of 33,8 % and 31,6 % respectively. Goal orientation (21,9 %) and working moral (21,5 %) is making a second pair as both were mentioned in over more than every fifth advertisement. Communication skills (16,9 %), willingness for self-development (16,3 %), positive attitude (15,7 %) and customer service orientation (15,6 %) makes one group as over 15 % of advertisements are looking for these competences/features. Organizing skills (11,0 %), creativeness (7,8 %) and flexibility (6,0 %) are also distinctive features. Willingness to travel (1,6 %), efficiency (0,6 %), and accuracy (0,04 %) made also to top ten list in some occupation areas.

Features scrutinized can be set under three kinds of categories: professional core competences, mindset and features which indicate magnitude of feature. All of these features cannot exactly wholly be set under the mind-set or under the core competence since e.g., management tasks typically include great deal of leadership - type communication, emotional intelligence and cooperation skills - besides of technical skills of a specific branch and knowledge from business management. Most wanted feature among the job advertisements was working experience which has to be set under category of magnitude identification. It is clearly understood to be an indicator of some kind of trusted quality or quantity.

3. Former study

Confederation of Finnish Industries made a study concerning the leaders' opinions of the small and medium size (SME) companies towards the competence of the Bachelor of engineering graduates. This study was executed in 2009 and 400 owner-managers and executives answered the inquiry. SME leaders highlighted a need for innovation and development skills and these skills, strengthened by general professionalism and practicality at work as mastering the basic skills. Study expressed that these basic skills varies from one industry to another. (Definition for basic skills in this study cf. Reunanen et al. 2012.) One of the most solid outcomes of the study was the fact that engineering education needs differentiation to be able to meet various requirements in practice. Figure 5 below shows that professionalism, development and practicality are somewhat equally prevailing keywords when the future engineering tasks are described - by over 80 % endorsement given. Innovation and entrepreneurship are also very well supported with over 70 % and 60 % share respectively. Research skills are appreciated to sixth place, but there is a distinctive gap between fifth and sixth place.

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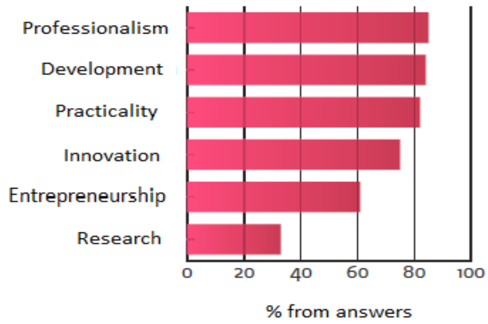

Figure 5. Keyword describes very well or somewhat well engineering tasks in future. (Modified from EK [17].)

This study also reveals that the future engineering tasks are highlighted with the following words, but there are no numerical data given to show their popularity ranking: foreman tasks, marketing, leadership, team leader gathering experts, organizational capability, employment issues from employees´ viewpoint, technical selling, resource management, implementation of development results, self-guidance, cooperation, team skills, organizational communication, communication knowledge, efficiency, creativity, work safety, training tasks, project and customer interface management, customer service, design/engineering and consultation and technology upkeep, and investment projects. This list of preferred issues shows that there are lots of different requirements set upon engineering education. It is remarkable that most of these issues are not exactly much related to the engineering itself, but rather to an organizational environment, business tasks and personal features/skills. Does this mean that engineers do not work so much with technology or engineering anymore?

Figure 6 below describes the issues which are preferred when it was asked about features giving the graduates the best readiness for future working life. Three most preferred issues are technical core knowledge and skill, values and attitudes, and practical engineering skills respectively. All of these issues are described to be the most important (over 50 % from answerers) when thinking what makes an engineer ready for working life. These are therefore the key features that must to be considered as "qualification factors", i.e., the core competences which cannot be forgotten even though these are not highlighted in every job adverts or even in task descriptions, excluding professionalism which most probably is meant to mean technical professionalism in engineering branches.

Figure 6. Features preferred describing the readiness for working life. (Modified from EK 2009.)

As it can be seen in figure 6, values and attitudes, communication skills, internationalization skills and organizational knowledge are issues which are highly respected for in a graduating engineer. These issues are wholly to be set under mindset category. Some parts from leader and team leading skills should also be set under the mindset section and some under the professional core competence since management (differ management and leadership) can be set under technical knowhow and methods. Therefore figure 6 also reveals the same crucial distinction between the technical core competence and the mindset. Graduating engineers have to "prove their worthy" by these professional qualification factors but also earn the work place by winning factors which are more prone to mindset category.

4. Comparison

When comparing results from job advertisement study and study from Confederation of Finnish Industries, it can be stated that similarities are quite remarkable. Both of the studies show that there are certain technical core competences which engineers should prevail and there are certain issues which are describing expected mindset of engineers. Technical core competences are naturally a bit different from industry to industry but the features of the mindset are very similar. Here below the both categories are listed as a combination of these two studies.

Most preferred technical core competences or professionally qualifying factors are:

- Up-to-date industry specific technical knowledge and skills
- Practical knowledge of IT and CAD programs
- Practical knowledge of design and engineering
- Management, leading and project knowledge and skills
- Foreign language and culture

Mindset or socially winning factors are:

- Values and attitude in general
- Cooperation and communication skills
- Self-development and self-management
- Customer and entrepreneurship point of views
- Creativity and innovation

In order to keep the UASs in the race about how to best satisfy the needs of both employers and employees, the above mentioned should be taken under careful scrutiny. In addition to top-ranked competencies, fresh engineering graduates must be equipped with a capability to constantly renew themselves.

5. Conclusion and Suggestions

When thinking about constant change and manners how to answer emerging needs and requirements of the employees of engineering personnel in the engineering related industries, it should be studied how well education will answer to the question of balance between technical of professional core competences and engineering mindset. What are these technical core competences in every engineering branch or economical area should be assessed situation by situation. E.g., it is totally different situation in machine engineering branches in South-West Finland compared to biotechnology branches in Netherlands. However, there are most probably some common concern regarding i.e. mindset and need for language or management issues and organizing skills.

This study reveals that suggested distinction between technical core competences and mindset is justified and neither of them could be disregarded or neglected when the future of an engineering education is planned. Next steps should be taken when industry and engineering branch related core competences are defined and exact skills and knowledge required are revealed for such a UAS technical education that consists of sufficient amount of both technical core competence and proper mindset. Reunanen et al. [18] gives one method for basic assessment of technical core competences, which method takes account an evolution of the core competencies by constantly justifying every curriculum whenever it is needed - also in the middle of individual study plans, instead of every second, third or even fourth year checking of a certain curriculum. That evolutionary method in the curricula planning guarantees the maximum flexibility for a student and up-to-dated core skills for the employers recruiting these engineering graduates. Using that method by combining it with an assessment of mindset issues, engineering education at UAS can be developed to reach totally new levels in order to serve companies and employees regionally and globally in the best possible manner.

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Curriculum Design

ICEE 2015

The Research Proposition and Professional Development for First Year Graduate Student Preparation

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Abstract

More than 20 years ago, we hypothesized that a formal introduction to graduate research, via proposal writing and presentation, would lead to a faster research startup and integration into lab groups than the traditional informal approach of entering a lab, conversing with personnel, and "learning by doing" This paper demonstrates the validity of that hypothesis when it was tested by >300 PhD graduate student participants in such a writing and professional development course sequence. The writing components are a 10 page (fall) and 15 page (spring) formal proposals including hypothesis development, proposal outlining, draft and revised written proposals, followed by practice and formal oral presentations .The professional development components include research ethics, intellectual property and patents, advisor expectations, and lab citizenship and management. As research is the defining difference between undergraduate and graduate study, the offering of research initiation courses such as these ought to become more widely practiced.

Keywords: *research, proposition professional development, graduate education*

1. Introduction

More than twenty years ago, our department initiated an independent course, Research Proposition, for all first year PhD candidates. Student performance in this spring semester three unit course was treated as a graduate qualifier exam, and both students and faculty have been supportive of this requirement, as summarized earlier. [1]

Over the last decade, our first year approach to research education has broadened. We added a one unit fall course, Introduction to Research, a professional development course including research ethics, ideation, outlining, presentations, and publications. While these two courses were satisfying as stand-alone efforts, recent faculty and graduate student sentiment pushed for an earlier engagement of student with research advisor, PhD committee, and research itself.

2. New courses: Professional Development and Research Propositions

In response, we have developed a yet broader first year experience encompassing a pair of two unit courses, one each in fall and spring. In the first, professional development topics are followed by creation of an independent, ten page research proposal. The second, spring semester effort requires the student, in consultation with her new advisor, to develop a NSF length proposal for the prospective PhD effort, and present it to her nascent PhD committee and course instructor. Additionally, earlier engagement with the PhD committee is now achieved through a January, second year oral report. The customary university Preliminary Exam occurs at the beginning of year three, and includes both a document (progress and plans) and an oral presentation. In summary, we now have the following early introductions to research:

Season (semester)		Activity	Deliverables
Fall	(1st)	Intro to research	10 p proposal: independent
Spring	(2nd)	PhD research proposal	15 p. proposal: collaborative, PhD plan
Spring	(4th)	Progress report	Oral presentation to PhD committee
Fall	(5th)	Preliminary exam	PhD progress & plans (document) and oral presentation to PhD committee

Taken together, these activities constitute a broad and continuing "Introduction to Research" including considerable practice opportunities in writing proposals (3) and delivering oral presentations (4). These formal structures guarantee that all topics central to setting the stage for a successful research PhD experience are encountered early in what is typically a five year effort.

This formal, "forced convection" approach is, we argue from experience, more likely to produce a prepared PhD initiate that the traditional, much less structured approach of simply joining a lab group, beginning lab research, and "swimming or sinking" in a nearly solo effort, otherwise known as "learning by osmosis."

Our approach is consistent with studies of "How People Learn" [2], Here Donovan, Bransford and Pellegrino propose that "To develop competence in an area of inquiry, students must (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in the context of a conceptual framework, and (c) organize knowledge in ways that facilitate retrieval and application"

We argue that our early introduction of literature searching and reading reviews and original articles centered around a simple hypothesis provides opportunity to initiate foundation knowledge construction, that the conceptual framework of writing in proposal format provides a focus for the student to demonstrate "understanding of facts and ideas in the (research) context", and that the written proposals and oral presentations repeatedly force the student to "organize knowledge in ways that facilitate retrieval and application."

The motivations for moving to our current two semester configuration were two, and we indicate by "Add" our responses to each:

Faculty: Desire earlier start on (funded) PhD research
 Add: 2nd semester PhD proposal
Graduate students: Seek earlier engagement with advisor and PhD committee
 Add: Advisor for PhD proposal (2nd semester)
 Add: Advisor to 2nd semester course faculty committee
 Add: Presentation in 4th semester to PhD committee

Both courses require that student construct a research proposal. The distinctive differences between the courses are:

Fall proposal demonstrates originality (student solo effort), while spring writing demands collaborative conversations with advisor.

Fall paper is accompanied by a 15 minute class presentation followed by graduate student questions and instructor written critique. The spring proposal is presented and defended in a one hour oral exam before four faculty including instructor, PhD advisor and at least one other member of the prospective PhD committee.

We believe that the student, having prepared the fall proposition on his own, is now in a strong position in the spring to crystallize advisor conversations and readings into a fruitful PhD proposal. Similarly, having faced instructor critique and classmate questions in the fall semester oral presentations, the student is better prepared for the more rigorous spring defence in front of a faculty committee.

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3. Fall Course

3.1 Course structure

The outline for the fall semester first course appears in Table 1. The calendar provides two lectures per week for topics 1-8, then one per week as seven due dates appear. This staged approach in which every step of proposal preparation and presentation has a assigned due date, with written or individual discussion feedback from the instructor, guarantees a timely completion of all proposals. The fall class has a single oral presentation to the class and instructor. The spring class follows a similar string of due dates for preparation of a second proposal in collaboration with the chosen PhD advisor. A practice oral presentation is given to the class and instructor before a formal presentation the last week to a faculty committee of four including the PhD thesis advisor and the course instructor

Table 1. Lecture - Discussion topics: Fall semester

1.	Introduction and Overview; "Research: The heroic quest"
2.	Introduction to Research Ethics:
3.	Electronic searching and library resources
4.	Identifying a research topic for your proposition.
5.	Research: Proposition structure and substance
6.	Thesis structure and style
7.	Writing Styles: informative, concise, and complete
8.	Advisor expectations of graduate research assistants
9.	DUE: Literature search: 10-15 PAPERS; 1-2 REVIEWS
10.	Critique of research papers
11.	DUE: Research critique of a paper
12.	Intellectual property & patents
13.	DUE: Proposition outline with references (two pages)
14.	The lab notebook
15.	Individual discussions: Research topic
16.	DUE: Proposal draft (8 pp) (returned Nov 8)
17.	Revising technical prose
18.	DUE: Final 10 page proposal
19.	Oral presentation tips
20.	DUE: DRAFT slides with individual discussions
21.	DUE: Oral presentations (15 minutes each)

3.2. Student fall semester topic selections

Students are free to select their fall topics, as with our earlier proposition course. [1] Student topic selections for a recent fall semester included a broad range of titles, which nonetheless could be classified into one of three categories: bio-related, materials-related, or kinetics and reactors (Table 2). These self-selected fall topics for new graduate students indicate no discomfort with current research areas, regardless of how distant they may be from traditional undergraduate course materials. Part of the "frontier" aspect doubtless derives from the fact that many entering graduate students now have had an undergraduate research experience.

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Table 2. Proposal titles for fall semester course

Bio-related
1. Increasing lipid productivity in microalgae cells via nutrient optimization
2. Nanoparticle membranes via functionalization with single stranded DNA
3. Biocompatible chitosan-coated hollow hydrogel particles for drug delivery
4. Liposomes with curcumin-encapsulated cisplatin for dual anti-cancer drug delivery
5. Imunoglobulins from MS patients contain metallic subfraction that hydrolizes myelin glycoprotein
6. Buanol via co-fermentation of T. Resei, R. erythroplis and immobilized C. beijerinckii.
7. Expression of thermostable scaffoldin protein in S. solfataricus
8. Site-directed mutagenesis of oxygen diffusion pathways in C. reinhardtii hydrogenase for enhanced oxygen tolerance
9. Phototrophic biocathode for enhanced biomass photosynthesis

Materials-related
10. Photon modulated On/Off switch via light oxidative voltage (LOV) protein.
11. Organic solar cells via combined nanotube-bulk polymer heterojunctions
12. Cation-exchange membrane formation via film forming and lamination
13. Increasing the efficiency of self-healing polymers
14. Lithium ion battery electrolytes for low temperature applications
15. Optimization of bulk heterojunction solar cells
16. Fullerene-coated carbon namotubes in ordered bulk heterojunction photovoltaic cells
17. Improved polymer composites via carbon nanotube reinforcement and selfhealing technology
18. N-substituted phosphoric acid doped polybenzimidazole protein exchange membrane for gas separations
19. Synthesis of transition metal-oxide heterostructured nanowires
20. Electrospun well–aligned nanofibers containing metal catalyst nanoparticles

Kinetics and Reactors
21. Tar and coke formation in hydrothermal gasification
22. Coupled partial oxidation and steam reforming for catalyzed hydrogen production
23. Modeling cellulose pyrolysis via molecular dynamics simulation
24. Heck reaction in supercritical carbon dioxide with palladium catalysts
25. Plasma assisted ammonia synthesis in a reverse-vortex flow gliding arc reactor

4. Graduate students

4.1. Pushing progress: Informal surveys

An in-class anonymous written survey motivates student progress and crystallizes planning through finite steps. This informal fall survey is conducted weekly in class and reported back to the student audience the same day (Table 3) until most queries are answered positively by most students. The public presence of a few “early bird” students typically galvanizes the others to “move up.

Table 3. Anonymous in-class survey

1. I have read at least one review article	(Yes/No)
4. I have read at least 5 original papers	(Yes/No)
5. I have chosen a (temporary) hypothesis	(Yes/No)
6. I have written a draft outline for my paper	(Yes/No)
7. I have found references for each part of my outline	(Yes/No)

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4.2. Evaluation by graduate students

Formal course evaluations for the first three semesters of the independent, fall proposal and the first two of the collaborative spring proposal appear in Table 4 below, a tabulation of our standard university course evaluations. These two writing courses fare well compared to our other department graduate courses (including reactors, transport, thermodynamics, and applied mathematics) and to the 1-5 absolute standard of our evaluation scale. Given the apparent initial hostility of new graduate students toward technical writing, these end-of-semester evaluations represent a significant achievement.

Table 4. Graduate student course evaluations: (Grad course / grad course dept average)

Course: (5.0 max)	Intro to Research Fall semester			PhD proposition Spring semester	
(% student participation)*	(84)	(65)	(46)	(67)	(47)
The instructor…	F 08	F 09	F 10	S 09	S 10
1. …stated course objectives	4.4/4.6	4.5/4.5	4.6/4.6	4.6/4.3	4.8/4.5
2. was receptive outside class	4.6/4.9	4.2/4.3	4.5/4.3	4.4/4.3	4.6/4.4
3. explained difficult materials	4.3/4.3	3.9/4.0	4.6/4.2	4.4/3.9	4.6/4.3
4. was enthusiastic re/teaching	4.6/4.5	4.2/4.4	4.6/4.5	4.6/4.3	4.4/4.4
5 was prepared for class	4.2/4.6	3.8/4.4	4.5/4.6	4.6/4.3	4.0/4.4
6. gave prompt, useful feedback	4.4/4.3	4.2/4.0	4.5/4.3	4.3/4.0	4.2/4.2
7. used instructional technology	4.1/4.5	3.3/4.2	4.0/4.3	4.3/4.3	4.2/4.4
8 treated students with respect	4.6/4.6	4.4/4.5	4.8/4.6	4.5/4.5	4.7/4.5
9. was an effective teacher	4.5/4.5	4.1/4.2	4.7/4.3	4.4/4.1	4.3/4.4
The course …					
10. …readings were valuable aids	4.4/4.5	3.6/4.2	4.3/4.2	4.6/4.2	4.3/4.3
11. assignments aided learning	4.6/4.6	4.1/4.3	4.5/4.4	4.8/4.3	4.1/4.2
12. was intellectually challenging	4.4/4.7	3.9/4.4	4.3/4.6	4.8/4.4	4.6/4.5
13. improved subject knowledge	4.4/4.6	4.1/4.5	4.4/4.6	4.9/4.4	4.6/4.5
14. was excellent	4.3/4.4	3.9/4.2	4.3/4.3	4.4/4.2	4.3/4.3

* Student completion of online university survey is optional, (unfortunately) not mandatory.

4.3. Importance of feedback

For our earlier, one semester proposition course (1), students rate as most valuable the "writing the rough draft, comments received on the rough draft, and giving a practice talk." Rated as generally helpful were "doing a literature review; writing the proposal outline (with references); preparing the technical presentation, and class questions after the practice talk." These qualitative reflections indicated that continual, formative feedback for every phase of proposal construction is important. The formal deliverables are the final paper and presentation and defense, but the greatest learning appears to have been in the exercises and feedback leading up to these final products.

Our newer, two semester sequence has been well received, as shown by graduate student evaluations (using a different, university imposed format) in Table 4. The grades here reflect that for the course vs the departmental graduate average for all graduate courses that semester, e.g., 4.4(course)/4.5(dept). We are pleased that these required writing and presentation courses are evaluated as highly by the students as are the more familiar engineering courses for this major: applied mathematics, reactor design, transport phenomena, and thermodynamics, topics which constitute the traditional core of chemical engineering.

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Accordingly, scheduling individual discussion times with students is important in emphasizing the pattern in research of ideation and critiquing. Two formal 20 minute discussion times with each student are scheduled for the following purposes:

1. After outline & hypothesis: "What is central hypothesis ? What are the key 2-3 papers for this proposal ? Why are these important?"
2. After submission of draft slides: Review/critique of all slides.

During final presentation, each student audience is required to create (at least) two questions for each presenter, and a 5 minute time period is allotted for student questions addressed to the presenter. Students also receive from the instructor a written critique of their final presentation.

5. Faculty

5.1. Instructor time commitment

These informal discussions are important to the student, and also constitute a substantial and necessary part of the instructor's time commitment to the course. For example, the fall two unit course includes two 20 minute sessions with each student, so for our two most recent years, class size was 20-24 students, hence 7-8 hours of discussions twice a semester. The final presentation at 15 min(fall) and 30 min (spring practice) and 1 hr.(spring final) /student add 5-6 and 30-36 hours of instructor contact per semester, respectively. These times commitments are partially offset by moving from two classes/week to one/week as the semesters progress.

Similarly, feedback regarding oral presentations is important. In fall semester, students complete a formal one page speaker evaluation form for each of our Monday departmental research seminars. Two days later, the first 10 minutes of our Wednesday class are devoted to discussing these evaluations to highlight what the seminar speaker did well, and where opportunities for improvement lie. First year students are particularly critical of speakers who fail to provide an opening introduction to the topic, to establish key vocabulary as well as an initial, accessible story line.

In the spring, our department hosts an annual Schoenborn Research Competition, named after our department's founding chair, Ed Schoenborn. Here, first year students again complete written critiques of the oral presentations by 6-8 PhD students in their final year, again followed by an in-class discussion of presentations. This research symposium also includes 24 posters by students near the mid point of their PhD work, with attendant poster evaluations and awards.

Collectively, these efforts establish a critical thinking atmosphere for research, in which every element (ideation, literature review, hypothesis generation and outline, drafting, final paper and oral or poster presentation) are subject to real time critiquing.

5.2. Evaluations: Faculty

After the first two academic years (08/09 and 09/10) of the present format, our faculty who had accepted new students in the two most recent years were surveyed to ascertain their assessment of the new spring student-advisor collaborative format for producing a PhD research proposal. Our questionnaire asked about changes in the speed and depth of advisor engagement, integration into advisor lab group, and encounters with the PhD committee.

The results in Table 5 (next page) show that faculty are strongly positive about the new format. The faculty have a longer experience in current and former proposal formats for the first year experience than do the grads. The table shows that the new format results in faster engagement with PhD research, advisor conversations, integration into lab groups, and conversations with PhD committees. We conclude that the new format fruitfully addresses the prior concerns of both our faculty and graduate students.

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Table 5. Faculty Survey: Spring research proposition course

AS-agree strongly, A-agree, N-neutral, D-disagree, DS-disagree strongly

	AS	A	N	D	DS
SPRING PROPOSITION					
The spring proposition …					
1. …increased speed of student engagement with (Ph D) research topic	8	7	1	0	0
2. …increased speed/depth of engagement with research advisor	5	9	2	0	0
3. … increased speed of integration into lab group	5	6	4	0	1
4. …led to earlier formation of PhD committee	6	6	3	0	1
5. …led to earlier engagement with (some of) PhD committee	5	9	1	1	0
6. … allowed earlier advising/counseling of student by advisor	4	9	2	1	0
SECOND YR PRESENTATION TO PhD COMMITTEE					
The second year (January) presentation..					
7. …gave earlier student engagement with full PhD committee	8	2	0	0	0
8. … showed evidence of faster student progress in research	2	7	0	1	0

5.3. Spring proposition: An original or an echo?

Graduate students are uniformly supported by outside grants. According, for each advisor topic offered to new students in our late fall student-advisor selection process, a funded proposal already exists. Whether the spring proposition course produces a novel proposal is suspect, but the defining purpose of spring is for the student to take ownership for framing his PhD research via his own efforts as well as conversations with his advisor. The spring mid-semester draft proposal is critiqued by both the course instructor and the PhD advisor. Thus the advisor feedback has substantial influence on both the direction and focus of the prospective candidate's research. Correspondingly, the spring advisor-student conversations required to initiate and focus the proposition guarantee a substantial, early student engagement with the advisor, as the faculty results above indicate.

Whether such spring effort is productive can also be judged by student evaluations. In Table 4, responses to statements 10-14 illustrate graduate student satisfaction with what was learned from the spring proposals as the responses were among the highest in the table. No student has complained that the second, spring collaborative proposition was a duplicative or repetitive version of the fall independent proposal !

6. Relation to prior work

The author is not aware of similar, extensive first year writing courses in other graduate departments, although the requirement for research propositions per se is widely found, often near the end of a thesis rather than the beginning. The need for early formal training in research writing is evident from a comment by Villareal [3]:

> "Scientific writing, like so much in academia is an acquired skill. It seems that transmitting writing skill is essential among the various aspects of scientific training. Most of my colleagues will agree that the one chore eliciting most consternation is the effort it takes to transform a young graduate student's first draft into a publishable manuscript."

Our view is that opportunity for such writing should not wait until the concluding years of PhD research, but rather begin on the first fall day of the graduate experience. While engineers and scientists are not widely regarded as willing writers, the fact that "student writers often do better work when their readings reflect their special interests" [4] indicates that the stereotype of the reluctant writer is incorrect, at least in graduate research.

7. Conclusions

Research is the dominant activity of graduate programs Consequently, formal training in aspects of research should be a logical part of first year graduate study. The present article illustrates how to smoothly engage new graduate students with their research topics and committees through construction, presentation, and defense of several written propositions. The courses described here have been taught in one form or another for twenty years, and have been strongly accepted and endorsed by both new PhD graduate students and their faculty advisors as the surveys reported here indicate.

These two courses could easily be taught elsewhere. Graduate student opportunity to write creative papers about research has been repeatedly shown to be productive via our twenty year history of these offerings, now to the order of 300 graduate PhD candidates. The total teaching load for such a course is similar to that for any three unity traditional offering. What is most different and required is the presence of an instructor dedicated to enhancing each student's story telling skill in the research domain.

8. Acknowledgement

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Candidates ranking models for entering the second and third degree of academic studies: multi-criteria approach

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Abstract

There has been an increasing interest of students in recent years for continuation of education at the second and third degree of academic studies. Since the accreditation of study programs significantly limited the number of students at Master and PhD studies the problem of ranking candidates has appeared. It is usually assumed that the main criteria for ranking should be the average mark from the previous study period, exam difference, if the candidates are coming from some other study programs, duration of the study program and scientific work of candidates. However, the problem arises from the lack of a model according to which these criteria would be calculated mathematically in order to be objective. This paper deals with two models: a model for ranking candidates for entering Master studies and a model for ranking candidates for entering PhD studies. The models are based on multi-criteria approach in which criteria and their weights are defined first and then the procedures of quantification and normalization of attributes follow. The presented models have been used successfully in the last three years at Technical faculty "Mihajlo Pupin" in Zrenjanin, the Republic of Serbia. These models can be more or less modified according to the needs and specific characteristics of concrete study programs but the main idea, mathematical, multi-criteria approach has to be kept. In this sense, a wider use of the suggested models is expected.

Keywords: *Master studies, PhD studies, ranking of candidates, criteria, multi-criteria approach.*

1. Introduction

The issue of students ranking for entering university as well as their scientific and research work is of significant importance in institutions of higher education. The issue is of practical and scientific character. There is literature which deals with these topics implying a possibility of achieving the best possible results in the process of student's selection [4] [20] [19]. However, the thing we consider the most significant in this paper is multi-criteria approach which is used in ranking and choosing candidates [2] [1] [8].

In order to facilitate the evaluation process, a methodology based on the analytic hierarchy process (AHP) was used. [1] Different evaluation scales have been used and each one is characterized by different levels associated to different fuzzy numbers. In the aforementioned research, the AHP has shown its strengths as a tool to make group evaluations. [1] An empirical study of a real selection problem at the Universidad de Occidente in Mexico is presented in a paper [8], by using the ELECTRE III methodology to construct a fuzzy outranking relation, and then a genetic algorithm to exploit it and to obtain a ranking in decreasing order of preference.

At Stanford some other factors are taken into account such as: background, experiences, perspectives, fit with Stanford GSB and its MBA Program, aspirations, values, and accomplishments [6]. Also at Harvard University for entering the graduate degree Transcript(s), GMAT/GRE, TOEFL/IELTS/Pearson Test of English, Essay and Recommendations are needed [7]. Therefore, it appears that many universities in the United States prefer the qualitative criteria at the selection of candidates. Probably this is the result of a systemic approach to the work of higher education institutions and confidence in the institutions of higher education. In contrast, in Serbia it is necessary to introduce quantitative criteria, in order to avoid any doubts about the objectivity of the committee, and in some cases lawsuits of candidates: in Serbia, candidates often do not recognize the opinion of the committee (qualitative criteria), so it is necessary to rank quantitatively the candidates and, predefine procedures, by numbers, proving the advantage of a candidate.

Hence, considering the institutions of higher education in Serbia, there is a need for establishing a unique, objective and reliable method related to ranking candidates for entering academic studies of the second and third degree, Master and PhD studies. The legal framework can be found in the regulations of the Law on Higher Education of the Republic of Serbia according to which universities are independent in creating the entering policy. Accordingly, candidates enter the second and third degree of studies under conditions and procedure determined by general act and competition for admission announced by an independent institution of higher education [21].

An institution of higher education determines, in accordance with the Law, criteria for classification and selection of candidates (success in previous education, the type of previous education, specific knowledge, skills, abilities, etc.). On the grounds of determined criteria an independent institution of higher education makes a list of registered candidates.

This paper presents a model for ranking candidates at entering Master and PhD studies (models for ranking future Master and PhD students). Both models are based on the principles of multi-criteria analysis where the available alternatives (in this case, registered candidates) are ranked according to a great number of criteria. The presented model has been used successfully in the last three years at Technical faculty “Mihajlo Pupin” in Zrenjanin, University of Novi Sad.

2. Multi-criteria analysis

Multi-criteria decision-making (MCDM) is related to those situations in which a number of, most frequently conflicting criteria, exist [10]. Classical optimization methods use only one method at making decisions. In this way, in a great number of cases, objectivity is considerably decreased at problem solving. Therefore, there are today fewer and fewer decision-making problems in which a choice is made on the basis of only one criterion. On the other hand, multi-criteria approach contributes to objective solution of these situations. Complexity of the real problems at decision-making often requires multi-criteria model, in other words, multi-criteria basis as an initial condition for objective selection and the choice of alternative solutions [14].

The field of MCDM implementation is wide but there are certain common problems which a decision-maker has to solve whly implementing the MCDM model: [3].

- Greater number of criteria which a decision-maker has to create taking into account all aspects of the problem.
- Conflict among the criteria (possible overlapping of criteria should be avoided).
- Incomparable measuring units, because the criteria often have different measuring units.
- Planning or choice: a decision-maker can plan or choose the best action from a union of previously defined final actions.

According to the last characteristic, MCDM problems can be classified in two groups: [10]

1. Multiattributive decision-making (MADM) and multi-criteria analysis (MCA). This group of MCDM methods solves the problems by choosing the best action from the group of previously defined ones.
2. Multi-objective decision-making (MODM). This group of MODM solves the problem by planning the best action.

MCA problems are present in a lot of real situations. For example, in business, there are the following situations: the choice of a manager, a new product, raw materials supplier, then, the choice of technical maintenance method, machines or equipment, etc. In the life of an individual, there are, for example, the following situations: the choice of a job, a car, a flat, a holiday house, a holiday destination, etc. [12].

The previous examples point at a wide field of implementing multi-criteria analysis but also at its complexity. Therefore, for this reason as well as for the system problem approach, multi-criteria analysis is increasingly used and pushes back some other methods. The examples can be found in various sources, such as: [11] [22] [5] [13] [9] [18].

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3. Candidates ranking model for entering Master studies

Upon finishing the application for entering Master studies it is necessary to rank the candidates. Ranking is carried out even in cases when there are fewer candidates than available places.

According to the Regulation of Technical faculty “Mihajlo Pupin” in Zrenjanin (2012) [16], the ranking of students/candidates who apply for entering Master academic studies is carried out on the basis of the following criteria:
C_1 – Average mark/success at the previous level of studies (Bachelor studies),
C_2 – Compatibility of the finished study program at Bachelor studies with the desired Master study program (given in evidence by the number of differential exams).

The choice of criteria has been imposed by the need to take into account the success at the previous level of study and also the compatibility degree of the previously finished and Master study program. In this way, the students with high average success from other faculties or different study programs are also given the chance to enter. (The Regulation defines appropriate scientific fields of the finished Bachelor studies. For example, for entering the study program at Master studies – Engineering Management, candidates have to finish Bachelor studies from Technical – Technology field of sciences or those from Social – Humanistic field.)

The criteria have different significance measured via their weights:
C_1 – Average success/mark at Bachelor studies $w_1 = 70$;
C_2 –Compatibility with the finished study program $w_2 = 30$;

Candidates are ranked according to the value of success index (SI). Success index of i-candidate (SI_i) is expressed by points (0 - 100) at two decimal numbers and is given by the following formula:

$$SI_i = \left(\frac{a_i - 6}{4}\right) \cdot 70 + \left(\frac{10 - b_i}{10}\right) \cdot 30\,; \tag{1}$$

where:
a_i –represents an average success/mark of the finished study program at Bachelor studie of i-candidate (practically, a candidate with an average success/mark 10.00 is assigned 70 points, the one with 8,00 is assigned 35 points and a candidate with an average mark 6.00 is assigned 0 point),
b_i – the number of differential exams of i-candidate (the number of exams that have to be passed due to incompatibility of the finished study program at Bachelor studies with a desired Master study program). If $b_i >$ 10, it may (but it does not have to) be adopted $b_i = 10$. (In other words, the sum is reduced by 3 points for each differential exam).

For instance, if a student has 10.00 average mark at Bachelor studies and 5 differential exams, his SI = 85. This situation is almost equal to the situation in which a student's average mark is 9.14 and there are no differential exams (the same study program at Bachelor studies).

For the criteria defined in this way the change (adjustment) of the proposed formula (1) can be carried out in two ways:
1. Change in criteria weights (weights distribution $w_1 = 70$; $w_2 = 30$ not compulsory).
2. The change in number of differential exams that is taken as (conditionally) a limit, in this case it is 10. If we take 15 differential exams as a limit, the formula will be:

$$SI_i = \left(\frac{a_i - 6}{4}\right) \cdot 70 + \left(\frac{15 - b_i}{15}\right) \cdot 30\,; \tag{2}$$

In the second case, (formula 2), for every differential exam the sum will be reduced by 2 points.

If two or more candidates have equal SI, the additional criteria are applied. The first of them is a duration of studying at Bachelor studies. If the difference in studying duration is less than one month, then a candidate with higher average success/mark at Bachelor studies is enrolled (second additional criterion).

If two or more candidates have equal SI even after additional criteria have been applied, other additional criteria have to be used: published scientific and professional papers, project participation, students awards.

4. Candidates ranking model for entering PhD studies

Upon finishing the process of candidates application for entering PhD studies, it is necessary to rank the candidates. Ranking is carried out in all cases, no matter the number of registered candidates, even when there are fewer candidates than available places.

According to the Regulation on entering PhD studies [15] at the study program Engineering Management – PhD studies (2012), ranking is carried out according to the following criteria:
C_1 – Average success/mark at the previous study levels (Bachelor and Master studies taken together),
C_2 – Duration of studying,
C_3 – Previous scientific and research work (scientific competence index).

This choice of criteria is imposed by the need to take into account previous success of students (expressed by the average success/mark at lower level),a duration of studying and previous scientific and research work of candidates. A degree of compatibility of the finished study program with the program of PhD studies is not valued here as a significant criterion. In our opinion, the mentioned compatibility is not so relevant at PhD studies in comparison to scientific and professional potentials of candidates which is best visible through the mentioned three criteria. In this way, equal chances are given to students no matter the faculty or the study program they have previously finished. (The Regulation defines scientific fields for the previously finished Bachelor and Master studies. For instance, if students want to enter the study program at PhD studies Engineering Management, they have to graduate at the field of Technical and Technology Sciences or Social and Humanistic Sciences).

The criteria have different significance, taken into account through their weights:
C_1 – Average success/mark at previous studies (Bachelor and Master studies valued together) $w_1 = 30$;
C_2 – Duration of studying $w_2 = 20$;
C_3 – Previous scientific and research work (scientific competence index) $w_3 = 50$.

It has to be emphasized that at the criterion C_1 the average of two average marks/success is observed (at Bachelor and Master studies), as well as that according to the Regulation, the average mark/success must be over 8.00. For this reason, in the formula (3) a constant 8 appears in the appropriate part of it.

The candidates are ranked according to the value of success index (SI). The success index of an i-candidate (SI_i) is expressed by points (0 - 100) at two decimals and is shown in the following formula:

$$SI_i = \left(\frac{a_i - 8}{2}\right)\cdot 30 + \left(\frac{b_{max} - b_i}{b_{max}}\right)\cdot 20 + \left(\frac{c_i}{c_{max}}\right)\cdot 50 \quad ; \tag{3}$$

where:
a_i – average success/mark at the previous levels of study of an i-candidate (average of two average values of marks/success at Bachelor and Master studies),
b_{max} – number of months spent at studying (both Bachelor and Master studies) for a candidate who, among all registered, has the longest study time,
b_i – number of months of prolonged studying time of an i-candidate,
c_{max} – scientific competence index (according to the Regulation on procedure and valuing and quantitative evidence of scientific and research results, “Official Gazette of RS”, number 35/07 [17]) of a candidate who, among all registered, has the highest index of scientific competence,
c_i – scientific competence index of an i-candidate.

For the criteria defined in this way the change (adjustment) of the proposed formula (3) can be carried out in three ways:

1. Change in criteria weights (distribution of weights $w_1 = 30$; $w_2 = 20$; $w_3 = 50$ not compulsory).
2. Change of the value b_{max}, should be defined in advance. For instance, it can be adopted that $b_{max} = 24$ months or $b_{max} = 36$ months. In any case,for all candidates who have $b_i > b_{max}$,it can be adopted that $b_i = b_{max}$.
3. Change of the value c_{max}, should be defined in advance. For instance, it can be adopted that $c_{max} = 20$ points or $c_{max} = 30$ points. In this case, for all candidates who have $c_i > c_{max}$,it can be adopted that $c_i = c_{max}$.

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If two or more candidates have equal SI, additional criteria are applied. The first additional criterion is the value of a candidate's scientific competence index (c_i).The advantage is on the side of a candidate with higher index of scientific competence. If two or more candidates have an equal SI_i and equal c_i, then the second additional criterion is the number of points of scientific competence index assigned from M21, M22 and M23 (internationals journals with SCI). The advantage is naturally on the side of a candidate with a greater number of points assigned from these categories.

If two or more candidates are equal after the application of the second additional criterion, then the following criterion are applied in sequence: project participation, experience in teaching at institutions of higher education.

4.1. The example of ranking candidates registered for entering PhD studies

One example of ranking candidates registered for entering PhD studies is presented in Table 1. (The names are not written due to data secrecy).

Table 1 Example of ranking candidates registered for entering PhD studies

No.	Name and surname	Average success/mark at Bachelor studies	Average success/mark at Master studies	Total	Extension of Bachelor studies (months)	Extension of Master studies (months)	Total extension of studies (months)	SCI	SI
1	Candidate 1	8.05	8.17	8.11	0	0	0	85.2	**71.65**
2	Candidate 2	9.88	9.38	9.63	0	0	0	30.5	**62.35**
3	Candidate 3	8.26	9.86	9.06	8	10	18	55.5	**56.06**
4	Candidate 4	9.53	9.59	9.56	5	24	29	32	**42.18**
5	Candidate 5	8.19	9.06	8.625	2	6	8	30.5	**41.76**
6	Candidate 6	8.04	8.86	8.45	1	0	1	12.5	**33.39**
7	Candidate 7	8.14	9.25	8.695	15	11	26	2.5	**13.96**

In this case, according to the formula (3), necessary data for calculation are:
$b_{max} = 29$; $c_{max} = 85.2$.

The examples of success indices calculation related to some candidates (SI_i):

$$SI_1 = \left(\frac{8.11-8}{2}\right)\cdot 30 + \left(\frac{29-0}{29}\right)\cdot 20 + \left(\frac{85.2}{85.2}\right)\cdot 50 \;= 71.65$$

$$SI_2 = \left(\frac{9.63-8}{2}\right)\cdot 30 + \left(\frac{29-0}{29}\right)\cdot 20 + \left(\frac{30.5}{85.2}\right)\cdot 50 \;= 62.35$$

$$SI_7 = \left(\frac{8.695-8}{2}\right)\cdot 30 + \left(\frac{29-26}{29}\right)\cdot 20 + \left(\frac{2.5}{85.2}\right)\cdot 50 \;= 13.96$$

5. Conclusion

The presented models have proved to be useful, objective and reliable in practice. They have been applied in the last three years at Technical faculty “Mihajlo Pupin” in Zrenjanin, University of Novi Sad. The models can be modified according to the needs and specific requirements of certain study programs and faculties. In this paper only basic possibilities of the proposed models for modification are presented (change, adjustment). However, no matter the modifications will or won’t be made and in what extent, the models keep the basic idea which is embodied in mathematical, multi-criteria approach. A wider usage of the proposed and similar models can be expected in some institutions of higher education.

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Integrating principles of Universal Design into the Engineering Education curriculum: Experiences from Norway

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Abstract

In recent decades the engineering education curriculum has changed from being purely technical oriented towards being more socially aware. Engineers need to be aware of the social impacts of their work and reflect upon the impact of their decisions. Most engineering studies have included elements of ethics for some time. During the last decade, environmental issues including renewable technologies have gained an increasing emphasis. A new trend is that legislature in various countries requires the presence of universal design, where the environment be as accessible to a large segment of the population as possible, be it a physically-built environment or the virtual environment. These new expectations also require engineers to be aware of the problems and the impact of their work and to be trained to design with universal accessibility in mind. This paper briefly reviews (a) the phenomenon of universal design, (b) the recent trends in standards and legislature, and (c) how these changes are affecting the engineering profession. Provided also are experiences incorporating universal design in engineering education curriculum at several Norwegian higher education institutions.

Keywords: *Universal design, Design for all, Engineering education curriculum, Social responsibility*

1. Introduction

The core of engineering education is the learning of mathematics, physics and technological subjects. However, most engineering study programs also include non-engineering subjects that are essential for the engineering candidates to practice as engineers. Some examples include economics, project management and language.

Many engineering subjects also include subjects along the ethical dimension that train students to reflect over the impact of their work and ethical dilemmas. Engineering students need to be aware of how engineers may affect the environment and the society. Both ethics and green subjects are common.

A new trend emerging in engineering education around the world is the issue of universal design [1], that is, engineering solutions should be accessible to all, or at least, as many individuals as possible. In the built environment, universal design means that individuals should be able to determine where they are, how to get somewhere else in the environment and physically be able get there.

In the digital domain, universal design means that computer solutions should be accessible by all so that all individuals have access to the functionality. Thus, if a society expects all people to use a solution, then it is important that it must also be accessible to all. A common example is the introduction of e-elections. It is a threat to democracy if the e-voting solution cannot be used by all that are entitled to vote.

1.1. Universal design

UN Convention on the Rights of Persons with Disabilities [2] defines universal design as follows:

> *"Universal design means the design of products, environments, programmes and services to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design. Universal design shall not exclude assistive devices for particular groups of persons with disabilities where this is needed."*

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The Centre for Universal Design at North Carolina State University defined the following widely accepted principles [3]:

1. Equitable use
2. Flexibility in use
3. Simple and intuitive
4. Perceptible information
5. Tolerance for error
6. Low physical effort
7. Size and space for approach and use

These general principles apply to both the physical world as well as the virtual world. In the virtual world, the W3C WCAG2.0 guidelines are commonly cited [4]. These guidelines indicate the best practices for designing web-pages that are accessible to all. The guidelines have four parts, addressing the following:

1. Issues related to the human sensory system (computer output)
2. Issues related to human motor action (computer input)
3. Issues related to human cognition (understanding)
4. Issues related to technical flexibility

Universal design has made its way into the legislature in many countries, and according to paragraph 14 of the Norwegian anti-discrimination law [5]; it states that (free translation):

> *"Information and communication technology (ICT) is defined as technology and systems that are used to express, create, transform, exchange, store, distribute and publish information, or that in other ways make information applicable*
>
> *New ICT-systems must be universally designed. This demand is applicable twelve months after standards or guidelines are available. All ICT-systems must be universally designed from January 1st, 2012. Exceptions can be given by the governing body if there are justifiable causes.*
>
> *The law applies to ICT solutions that support the ordinary functions of organizations and which are the main system that target or are made available to the general public."*

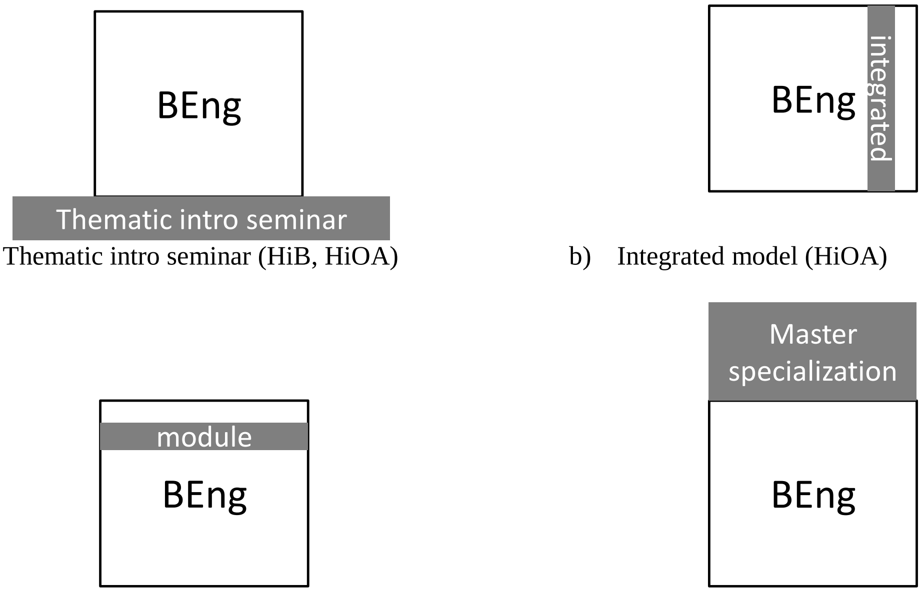
In other words, universal design is not an option, but a formal requisite. Engineers responsible for designing such systems therefore need to have sufficient knowledge, skills and general competences to ensure universal design.

2. Core knowledge, skills and general competences

Engineering students and computer students specifically, generally design systems with themselves as reference; in other words, they design systems that they like themselves. This is problematic since young individuals are commonly at a physical peak of their lives. These students are often more computer literate than the general population and are therefore also more tolerant of insufficiently designed systems. The foremost learning objective is thus to make the students aware that they are to design for the least common denominator. Also, it is essential for the students to learn that systems and ideas need to be tested on various target groups. Hence, they need to acquire basic usability testing skills.

Next, the students need basic understanding of human physiology, that is, the sensory system, motor system and cognition as well the consequences of reduced functioning. As known, human physiology deteriorates with age, indicating that these issues will be relevant for all at some time in the future. Often students tend to claim that disability is a narrow and specialized subject. A core goal is thus to change and widen the students' perspectives on the issue of disability. For example, if designing an online store that discriminates certain groups because of poor design, the owners of the store will likely lose business within a short period of time. By making the store more accessible, the owners will get access to a larger market. In other words, accessible design is both ethically correct and also economically-sound from a business perspective.

Connected with this issue is the goal of making students appreciate diversity, viz., to design inclusive systems that embrace diversity, displaying neutrality to gender, age, sexual orientation, functioning, political standpoint, cultural origin [6]-[8], religion, etc. The objective is to design for self-service and individual freedom which will give citizens the dignity to manage on their own in various situations [9].



a) Thematic intro seminar (HiB, HiOA)

b) Integrated model (HiOA)

c) Module (HiG, HiOA)

d) Specialization (HiOA)

Figure 1. Curricular models for universal design

A broad perspective on who potential users are is therefore essential. Diverse student group work is one way of learning about the value of diversity in practice. The personas methodology is another way in which students can explore diversity.

Our main goal is to develop a positive attitude among students where the design constraints become inspiring design challenges with a competition to achieve the best solution. Computer students are often fascinated by achieving the near-impossible, be it novel and effective algorithms, making hardware do tasks it was not meant to, etc. The aim is to tap into these interests.

3. Curricular models

We have identified four models in which universal design is incorporated into the curriculum in Norway, namely, thematic intro seminars or summer schools, integrated model, module based, and specialization. These four models are discussed in the following sections.

3.1. Thematic intro seminar

Bergen University College (HiB) has experimented with thematic intro seminars for several years (see Figure 1a). Their scheme has involved first-year students from the departments of the built environment, computer science and health sciences. Typically the seminar is run midway through their first semester from one to three days. The intro seminar has comprised general introductory and theoretic lectures from various experts in the field, followed by practical exercises. The students are organized into multidisciplinary groups comprising engineering and health science students. Together, they had to simulate various disabilities and then used the public transport system to get from one part of Bergen to another. Initially, the seminar ran for three days, but has subsequently been cut to two and one days, respectively.

At Oslo and Akershus University College of Applied Sciences (HiOA) we have offered an international summer school in universal design and ICT for two years running [10]. This initiative can be classified as a thematic intro seminar, but is partially also a module as our summer school is running for longer than the initiative at HiB, that is, three-weeks intensive. The purpose of the summer school is to prepare international students for the master program by giving the students the necessary prerequisites they may not have obtained from their home institutions and to prepare national students from other disciplines.

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Generally, the thematic intro seminar is relatively simple to realize as long as one can set aside time in the students' semester schedule. Another benefit of the seminar is that it mixes students from widely different fields who have to work together. It is advantageous that this occurs early in their studies.

One problem with the scheme is that the students may fall behind and disappear if participation is not compulsory or there is required or assessed coursework associated with the model. Another issue is that the learning effect may be limited if the content is not reinforced later on in their studies. A one-day or three-day seminar may not be sufficient to imprint good design practice in the students. A final challenge with the model is that it typically involves a small group of dedicated individuals. There is a chance that the other members of staff take a minimal interest in the initiative and the chance that students will meet the topic later on in the various modules are limited.

3.2. Integrated model

In the integrated model, universal design is taught as an integral part of the entire curriculum, where relevant issues (when relevant in the various courses) in universal design are introduced (see Figure 1b). This can, for instance, be special lectures with a special subject. Universal design can be taught in software engineering where students are exposed to software development method that embraces diversity. Obviously, human-computer interaction courses can easily be filled with content related to accessible user interfaces [11]. Another example is economy, where students can be aware of the legislature governing purchasing and tenders.

This integrated model is probably the best way to include universal design into the curriculum since all the students are exposed to the subject of universal design. Moreover, the various aspects of universal design are placed in relevant contexts in the various modules which help promote learning. Next, the integrated approach is likely to enhance learning as students encounter universal design at several stages of their study.

As of now, we are not aware of any bachelor programs that fully employ the integrated model. At HiOA we have partially landed on the integrated model because many faculty members are actively involved in the universal design research group and dedicated to universal design. There are therefore traces of universal design in several of the courses on offer for the computer science students.

Unfortunately, it is hard to realize the integrated model for the same reason, as it is hard to integrate ethics and environmental issues in the curriculum. The model is dependent on the faculty being familiar with universal design and also interested in universal design to some extent.

3.3. Module based

The module based approach is probably the most common in Norway because it is the easiest to realize (see Figure 1c). In this model, the topic of universal design is introduced in either a compulsory or optional course. This allows the students to get some in-depth knowledge on the topic. It requires only one, or very few, faculty members to have universal design competences. This model is employed at HiOA and at Gjørvik University College.

At HiOA, there is a 10 ECTS course in universal design for the computer science students [12], which runs in the third year of the bachelor programs. This means that students already have a basic foundation in computer science from their two first years of study. Gjøvik University College (HiG) offers a more general 15 ECTS distance learning course on universal design that focuses on the built environment [13].

A challenge with the model approach is that bachelor programs, especially in engineering, often have too many constraints and little flexibility for courses that are a bit off the beaten track of the core engineering courses [14]. At HiOA, the universal design course is only optional for the computer engineering students, while compulsory for the non-engineering computer students. Some students decide to opt for different modules and end up not taking this course. Consequently, they will have gaps in their knowledge.

3.4. Specialization

The last model described herein is universal design specializations (see Figure 1d). At HiOA we have developed an international master program in universal design and ICT [15]. It is a 120 ECTS master program, with two years of full time study. The structure of the program is listed in Table 1. The course comprises six 10 ECTS courses on various related topics, including introduction to universal design, ICT barriers, academic writing, research methods, advanced interaction design, globalization, intelligent user interfaces and a 60 ECTS individual project which runs over the last three semester with a build-up from 10, 20, 30 ECTS for the respective semesters to ensure that the students develop feasible and relevant projects.

Table 1. Structure of the international master program Universal Design of ICT.

1st year		2nd year	
1st semester	2nd semester	3rd semester	4th semester
Universal design	Interaction design	Optional courses	Master project
Research methods	Academic writing	Master project	Master project
ICT barriers	Master project	Master project	Master project

One benefit of running a specialization in universal design is that students do get an in-depth knowledge on the topic. Also, the applicants will hopefully be more motivated to study the topic and have ambitions to secure a career as a universal design and accessibility expert. The drawback of this approach is that only the students who decide to study this specialization acquire this knowledge. At HiOA we attempt to recruit our own bachelor students to the master specialization by introducing the topic at various stages to the bachelor students.

Recent signals from the Ministry of Education and Research indicate that master programs are to become less specialized and more general. It remains to be seen if we will eventually be instructed to widen the scope of the program.

4. Experiences

At the Institute of information technology at HiOA, there has been a strategic investment in universal design. One of the obvious and immediate benefits we experience is improved gender balance. At the master specialization in universal design, it is close to equal gender balance, while the bachelor programs in engineering are male-dominated. Our non-engineering computer bachelor programs have a higher ratio of females than the engineering disciplines.

One explanation for the improved gender balance achieved with universal design is that the goal is to help individuals specifically and mankind in general. This is a noble goal. On the other hand, plain engineering is driven by a sole interest in the technology.

Another effect of the strategic investment in universal design is more multidisciplinary staff and students. Universal design is itself a multidisciplinary field that have commonalities with many subject areas from sociology, health science and engineering. Experts from all these areas increasingly have to work together in the future in order to solve the challenges of the ageing population.

However, could the increased multidisciplinary tendencies be a problem? Are we facing a social science that creeps into technological subjects? There is undeniably a dichotomy between the technological versus the human perspectives. There are also an increasing number of faculty members with backgrounds from social science and other non-technological fields. Although the phenomena surrounding universal design are interesting in their own right, they should not draw attention from the core issues of technology as the society has a need for newly graduated engineers with a technological inclination and capability to handle difficult technical problem solving.

Another observation we have made is that faculty members drawn towards universal design often have a personal stake either being disabled themselves or with disability in their own family or network of friends. The question is whether this is an advantage or disadvantage. Understandably, these individuals have first-hand experience and knowledge. However, the phenomena associated with universal design are wide and personal experience is not likely to suffice. One further issue is that of neutrality and balance. Will a person with a certain personal standpoint be able to neutrally handle the rather wide subject matter in a balanced manner?

Although the subject of universal design has been around for several decades, it is hard to find faculty members with updated knowledge, thus further complicating the matter. The most challenging aspect we have experienced is that it is difficult to recruit students for the master specialization.

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5. Conclusions

This paper has addressed the universal design competences of engineering students in Norway. Four models of incorporating universal design into the curriculum have been discussed, namely, thematic intro seminar, integrated model, module based, and specialization. Based on our experience thus far, it seems that an integrated approach is probably the most beneficial option, since all the engineering students are exposed to universal design. Moreover, the integrated model allows the students to see the universal design in context. The fact that they encounter universal design several stages in different contexts is likely to reinforce learning. A challenge with this approach though is that a majority of the faculty members need competences and interest in universal design.

Future work includes further develop the curriculum at bachelor and master level to achieve an integrated approach to universal design. We also need to collect further experiences. In addition, the facts and benefits of universal design needs to be promoted more broadly and educational institutions needs to be motivated to incorporate universal design dimensions in their study portfolio. The benefits to individuals and the society at large need to be clearly communicated.

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A new introductory course in the engineering education at the University of Tromsø

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Abstract

In 2011 a new national curriculum for the education of engineers was established in Norway. The objective of the curriculum is to ascertain that engineering education is professionally oriented, integrated, research-based and has a high academic standard. Institutions are instructed to facilitate a holistic approach to the engineering profession, which integrates social science, technology, science and mathematics. A new introductory course for engineers was defined, and since 2012 every education institution in Norway has given freshmen engineering students the introductory course. The course should focus on the common aspects of engineering rather than discipline-oriented topics, motivate and create identity, and include social science. The guidelines accompanying the course are vague and it has been a challenge for academic staff to establish and run the introductory course. A survey has been carried out, and this paper presents the status of the introductory course three years after implementation. Examples from various engineering programmes in Norway will be presented. At UiT the course is called "Introduction to Professional Engineering Practice and Working Methods" (10 credit points). The course changed from 2012 to 2014, and new changes are considered for 2015. It is a "toolbox" for the students with elements useful in engineering: CAD, project work, report writing, laboratory work, data analysis, engineering economics, introduction to history of technology, technology in society and engineering ethics. The course gives an overview of the engineer profession with lectures from local industry. Different experiments include model wind turbine; measurement of dust in suspension; measurement of air quality; level, pressure and flow control in fluids; and measurement of temperature with different instruments.

Keywords: *Introductory course in engineering education, Norwegian curriculum for engineering education, toolbox for engineering students.*

1. Introduction

In 2011, a new national curriculum for the education of engineers [1] was established in Norway. The objective of the curriculum is to ascertain that engineering education is professionally oriented, integrated, research-based and holds a high academic standard.

The institutions are instructed to facilitate a holistic approach to the engineering profession which integrates social science, technology, science and mathematics. A new introductory course was defined, and since 2012, every engineering education institution in Norway has given freshman engineering students the introductory course.

The course should focus on the commonalities of the engineering profession rather than discipline-oriented topics, motivate and create identity, and the course should include social science. The guidelines accompanying the course are vague and it has been a challenge for the academic staff to establish and run the introductory course.

The Department of Engineering and Safety [2] has four bachelor degree programmes in engineering: Automation, Process and Gas Technology, Nautical Engineering, and Safety and Environmental Engineering.

2. National Programme and survey of introductory courses

This chapter gives an overview of the national programmes for engineering education, and a survey of the introductory course in Norwegian engineering education.

2.1. National guidelines for engineering education

The new national guidelines for engineering education [1] was approved by the Norwegian Ministry of Education and Research in February 2011 and implemented by the education institutions at the start of the 2012 autumn semester. The guidelines gives a detailed description of the education of engineers. In chapter 2, learning outcomes (qualification) of engineering education is defined as:

- Knowledge
- Skills
- General competence

The learning outcome is specified and explained. The programme should ensure equality in learning outcomes between the institutions and facilitate mobility. Common to all programmes is that institutions should be able to document how the national qualifications are obtained in the study programme, as well as study field and course level. The students will achieve the same learning outcomes. The institution has the freedom to choose the content, organization and assessment used to achieve the results.

In chapter 3 [1] general guidelines for the structure and contents are described using standardized national terminology. A study is made up of courses and groups of courses. A degree in engineering has four subject categories, where some courses are compulsory, and other topics are elective to define an education profile. A programme of study is a coherent course of study made up of topics and topic groups. A study may have several specializations.

A programme of study consists of programme modules, and the individual courses that will collectively fulfil the requirements for learning outcomes. Curriculum name and description must be in accordance with content. Information and communication technology are integrated and used as a tool in education, both technical and pedagogically. Institutions should have close contact with the relevant sectors of engineering during both preparation and implementation of the programmes.

A bachelor's degree in engineering is obtained after completion of the study. The candidate must have passed at least 180 credits consisting of the following subject groups:

- 30 credits common topics (mathematics, engineering professional systems thinking, and introducing methods for engineering profession and work)
- 50 credit programme topics (technical subjects, science (physics and chemistry) and social studies)
- 70 credits technical specialization courses for each engineering programme, including the bachelor thesis
- 30 credits elective courses

Chapter 4 [1] “Characteristics of new engineering education”, states that quality in engineering education is described by characteristics and associated indicators. Characteristics and indicators will contribute to the continuous development of quality. An education of high international quality demonstrates these characteristics and performs well against the indicators. The characteristics give institutions the opportunity to compare programmes across institutions. The characteristics are:

I. Integrated and holistic education
II. In front of professional updating
III. Updated and varied teaching and assessment
IV. Research and development orientation
V. Profession competence and practical skills
VI. International competence
VII. Interdisciplinary, innovation and entrepreneurship
VIII. Student effort and study mastery
IX. Engineering formation

This chapter also gives a detailed description of the characteristics. For the introductory course, characteristic VIII emphasize the engineering profession. The group of common topics will contribute to the students study mastery, motivates and raises awareness about the student’s choice of study, and provides training in study skills. Computing training, writing practice, reading instruction and presentation skills are a focus of the study.

Chapter 5 [1] of the national guidelines specifies indicators for successful application of the characteristics of VIII. These are:

23. The study environment, teaching and learning methods, and assessment stimulates to increased student effort and study mastery.
24. The first semester motivates for the engineering profession and study programme, and stimulate the study environment for the field of engineering, and across study programmes.

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Chapter 6 [1] of the national guidelines specifies learning outcomes for programmes for civil engineering, computer science, electrical, chemistry and mechanical engineering, and for selected topics like mathematics, sciences and social studies. It also gives a detailed description of the introductory course and a learning outcome description in attachment 4.

2.2. Survey of introductory courses

The survey ([3] first presented by T. Schive at a national conference) is based on a review of course descriptions and syllabuses for a variety of introductory courses at Norwegian university colleges and universities. The survey took place three years after the new curriculum was implemented. There are fifteen colleges and universities in Norway that offer engineering programmes at the bachelor level. Engineering educational programmes have very different sizes, from Bergen University College, with more than six hundred engineering students per year, to Sogn og Fjordane University College with approximately thirty engineering students per year. Table 1 provides an overview of institutions with engineering programmes, the number of introductory courses per institution and number of students who graduated in the introductory course in 2013 per institution (data from database of higher education, DBH [4]). The table also shows obtained documentation in addition to course descriptions.

Table 1. Introductory courses in Norwegian engineering educations [3].

Institutions (UC - University College)	Number of intro. courses	Total number of students on intr. courses	Documentations from 2014
Buskerud and Vestfold UC	2	256	Syllabus (Vestfold)
Aalesund UC	2	150	Syllabus for automation, computer science and civil engineering
Bergen UC	5	616	Syllabus for electro, chemistry, project for civil engineering
Gjøvik UC	2	209	Lectures online
Narvik UC	4	295	Syllabus and project info
Oslo and Akershus UC	5	411	Syllabus for chemistry, web resources for Electrical and Electronic Engineering
Østfold UC	2	178	Syllabus (all engineering programmes)
Sogn og Fjordane UC	1	30	-
Sør-Trøndelag UC	6	501	Project info for Chemistry and Materials Technology. Syllabus for Chemistry, Computer Engineering, Materials Technology, Electrical, Mechanical and Logistics Engineering
Telemark UC	1	171	Syllabus
Stord/Haugesund UC	1	140	-
Norwegian University of Life Sciences	1	-	-
University of Agder	1	362	Lectures online
University of Stavanger	5	441	Project for civil engineering
UiT – The Arctic University of Norway	1	101	Syllabus

Online course descriptions are reviewed for all introductory courses, but because the course descriptions can be very general, it has been necessary to obtain curricula etc. from fall semester 2014 for some of the introductory courses. Teaching plans usually provide a detailed overview of the teaching programme on a weekly basis, with a brief description of the professional content. The documentation is supplemented with phone calls and email correspondence when there has been a need for clarifications, and such communication has mainly been with professionals who teach the introductory course.

It is common that the institutions have several variants of the introductory course, either in the form of several course codes or parallel sessions in a common course. In total, there are about forty varieties of the introductory course in Norway. In some cases, there are practical reasons for having more than one introductory courses, e.g. to split the production of credits between departments or because the institution has several campuses. All study programmes have defined one course of ten credits as the programme’s introductory course, but the course name may vary. There is no study that has split up the introductory course, or merged it with other topics. The introductory course is usually in the first semester. Colleges in Bergen, Oslo and Sør-Trøndelag who have high student numbers, have separate introductory courses for each engineering education programme, for example: civil engineering, computer science, electrical, chemical and machine engineering, and these are taught independently. At several university colleges, the introductory course consists of one common part with a general theme, and one study specific part. University colleges with few engineering programmes and few students choose to give one introductory course (due to limited resources).

3. Introductory course at UiT

This chapter presents course description and implementation at the UiT – The Arctic University of Norway.

3.1. Course description

At UiT the course is called “Introduction to Professional Engineering Practice and Working Methods” (10 credit points). The course description [5] is almost identical to the national guidelines. The following description is from the automation programme 2014 (which is identical to the other programmes).

Contents:

- Engineering profession, the engineer's role in society
- The history of technology
- Using computers/software
- CAD (Computer Aided Design)
- HSE (health, safety and environment)
- Measurement techniques
- Data collection methods
- Project work, project organization, report writing
- Ethics

Knowledge:

- The candidate has a basic understanding of the engineering profession and the engineer's role in society and workplace.
- The candidate has knowledge to see technology in both historical and forward-looking perspective.
- The candidate is familiar with scientific working methods and has a basic knowledge of project working both with respect to organization, implementation and reporting.

Skills:

- The candidate can identify engineering issues, seek the necessary information and assure the quality of this as a basis for problem solving.
- The candidate is familiar with basic processes of innovation and innovation in connection with project work.
- The candidate is familiar with methods of data collection.
- The candidate may use technical drawing as a communication aid.

General competence:

- The candidate is aware of environmental and ethical consequences of technological products and solutions.
- The candidate is familiar with how he/she can share their knowledge and experiences with others, both written and oral, and can cooperate in a group.
- The candidate can use modern computer tools in their engineering.

Course form: Lectures, project, laboratory and exercises.

Assessment is based on an individual examination within CAD (40%) and a written examination (60%). To participate in the written examination, the project - as well as any other requirements for compulsory work must be approved. To participate in the CAD examination, mandatory work in this subtopic must be approved. Both parts must be passed to achieve a grade. The grades are A-F.

3.2. Syllabus and implementation

The syllabus is a detailed description of the weekly content, responsible lecturer, working requirements and an index of literature. The smaller topics (like history of technology, ethics, engineering profession, energy theory, intellectual property rights (IPR), report writing and project theory) are spread out between the larger parts (computer aided construction; electro technology; measuring technique; data collection and analysis; laboratory and project work and engineering economics).

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The course is a “toolbox” for the students with elements useful in engineering education: CAD, project work, report writing, laboratory work, and data analysis. Other topics are placed in the introductory course because they are too small for a course of ten ECTS, and do not match other topics or courses. Those topics (like engineering economics, ethics, IPR, HSE) are relevant as a professional engineer.

The overview of the engineering profession presents a broad selection of engineering work, working conditions in Norway, and job prospects in local industry for UiT engineering programmes. One of our former students working in a local company gives a lecture of his working experiences.

History of technology gives an overview of national and local industry and the (offshore) oil industry. Also the perspective of what you need (of tools and technology) to survive in the arctic from the first inhabitants after the last ice age 10 – 12.000 years ago. The importance of marine (fishery) and maritime (development of boats), local natural resources (minerals and mining, hydroelectric power, fish), cornerstone businesses, industrial clusters, space science and earth observation (from satellites), innovations and research-based new business are highlighted.

In ethics, there are lectures with formal definitions and discussion groups on ethical dilemmas.

3.3. Computer Aid Construction (CAD)

Computer Aided Construction (or Design as in the acronym CAD) is in the first part of the course where students learn to use Inventor [6]. Software training in computer-aided design (CAD), where students make 3D-models of physical objects and produce engineering drawings, is included in the introductory course. The motivation for including CAD in the course is to provide a tool for the core engineering activity: the design and development of technical devices. Engineering drawings in general are considered relevant for all engineering branches, and the students are introduced to the standardized ways of communicating technical solutions through drafting and drawings. The CAD-training is mainly taking place in a PC-lab where the students are using the Autodesk Inventor computer software. Their skills are developed through practicing under supervision. The CAD-training is threefold, they produce their own parts electronically, they learn how to assemble parts into technical devices, and finally they learn how to make standardized technical drawings. One of the assignments consists of modelling a pipe clamp (Figure 1) which is handed out to the students, and they present their solution by standardized engineering drawing. The pipe clamp is chosen because it demands a variety of techniques for modelling.

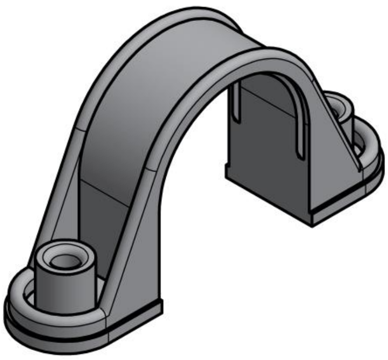

Figure 1. Pipe clamp.

In 2013, the assessment was based on a so-called reversed engineering task where students were asked to choose their own tool, component, gadget, toy etc. The students were given two weeks to model the chosen physical object. The lecturer approved the proposed object on the date the exam commenced. The examination answer consisted of engineering drawings of the model, and the physical objects were handed as guidance for the external examiner. The assessment was based on the level of difficulty and extensiveness of the modelling, and the quality of the engineering drawings. The exam contributed positively to the learning outcome, but more than a hundred unique drawings made the assessment too time-consuming. Figure 2 is an example of an exam answer.

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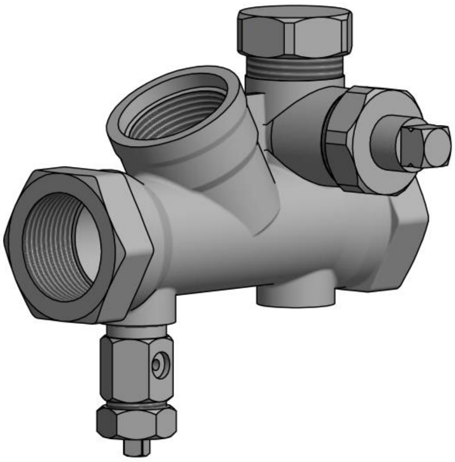

Figure 2. Example of a component.

3.4. The project

The project is to perform an experiment in which students work in groups of 3-5 (preferably 4). The project content:

- Plan the project with detailed plan for the experiment, measurements, and data collection.
- The plan must be approved by the supervisor.
- Carry out the experiment and data collection
- Analyse the data and make a conclusion
- Write the report (following guidelines for report writing)
- Report and data analyses (in Excel) is delivered through Fronter (UiT’s Learning Management System)
- The report will be commented by the supervisor before final submission.
- If the report is not approved, a revised report has to be delivered after a week.
- The report must be approved to get access to the final exam.

From 2011 to 2013 the students could select different experiments:

- Power production of model wind turbine.
- Measurement of dust in suspension.
- Measurement of air quality.
- Level, pressure and flow control in fluids.
- Measure of temperature with different instruments.

In 2014 all students carried out the same experiment, measuring temperatures with several instruments. The reason for this was that the department (IIS) moved in to a new building on campus, and the laboratories were not complete.

As an example, details of the wind turbine experiment are described ([7], figure 3). In the theoretical part of the report, the background of wind power, construction of the wind turbine and the power production of wind turbine is described. In the experiment, wind speed from the fan can be varied (and measured with anemometer), different blades with different profiles (aerodynamic characteristics), number of blades, and the pitch of the blades can be varied. The project plan must describe the experiment. The power of each experiment is measured and analyzed. The experiment should verify that wind power in an open air stream is proportional to the third power of the wind speed, proportional to the area described by the turbine, and proportional to the density of the air (Wikipedia, [8]). In addition, the best blade profile and number of blades under different conditions should be verified.

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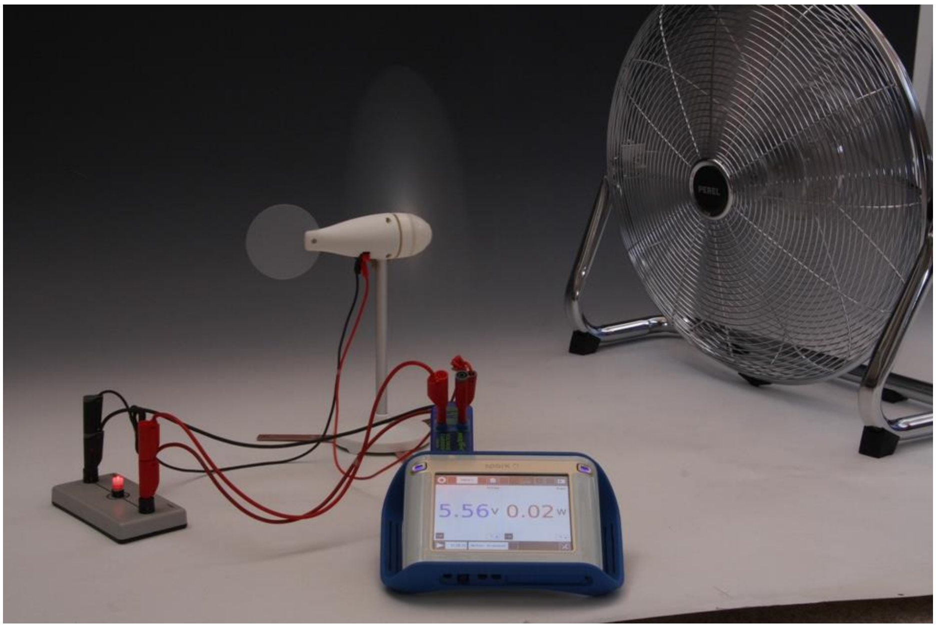

Figure 3. Wind turbine experiment [7].

4. Conclusion

The national framework has several elements that must be included in the education of engineers. The introductory course includes several of those; it also gives the student a useful toolbox for further study.

The survey indicates that there are large variations of the course in the Norwegian engineering programmes.

At UiT, the course has been revised from 2012 to 2014, and new changes are considered for 2015. In 2015, the projects will be specific for each engineering programme, and the teachers of each programme will be responsible for supervision and define an experiment relevant for the programme, similar to the experiments from 2011 to 2013.

The structure of universities and university colleges in Norway is changing, the number of engineering programmes will be reduced, and the same programme will be offered at several campuses. As a result of the process, UiT are merging with Narvik University College, which has several engineering education programmes. The plan is to coordinate the study programmes from 2016. This will include the introductory course.

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Make Engineering Curriculum Flexible: an Experimental Design in China

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Abstract

As the rapid development of manufacturing industry and engineering science, engineering education faces new challenges for the need of quality engineering graduates. On one side, the engineering and science have merged together when nano-technology goes more and more into products and industries. The manufacturing engineers need more frontier science thought and knowledge in even industrial applications. On the other side, the industrial competition for the variety of products and the new manufacturing technology development require entrepreneurial engineers capable to understand the problem and provide innovative solutions. At Tsinghua University, Beijing, China, an experimental reform of current curriculum of Mechanical Engineering is undertaken to enhance the flexibility of knowledge content and the way to inspire student learning, particularly for life-long learning and engineering practice with integrated knowledge. Principles and design consideration are introduced and discussed in the paper.

Keywords: *Innovation, Curriculum Reform, Practice in Engineering Education.*

1. Introduction

Tsinghua University is a top university in China, particularly in engineering majors. For a long time, graduates from Tsinghua have taken the leadership in the economic and industrial development in China. In recent years, Tsinghua has recognized the need for change in engineering education, to catch the change in the rapid development of engineering science and the change in industries, and to lead the further development in China and in the world.

Requirement of quality engineering professionals. The development of industries and the science/technologies brings new requirement of quality engineering professionals, and in turn raises new challenges to engineering education. For example, in 19th and the first half of the 20th Century, training professional engineers was the goal of engineering education. Early engineering programs focused on providing their graduates with considerable hands on experience. When mathematical methods were developed further for modelling and analysing the design functions and production processes, Applied

Mechanics gained acceptance increasingly. In the second half of the 20th Century, the desired engineering professionals were scientific engineers. As the development of basic and applied science, engineering became much more science based. The differential equations and computational tools became available and utilized to provide meaningful solutions to industrial challenges, as examples. This has, to a large degree, continued until the present time. In the early nineties of last century it was clear that more than science was needed and many schools started to emphasize non-technical skills such as teamwork and communications. Then stared in the 21st century, the entrepreneurial or innovative engineers have become desired or expected outcomes from the engineering education. General technical skill may no longer be a distinguishing feature that commands high salaries. The ability to identify new needs, find new solutions, and to make things happen will be required of every successful engineer[1, 2].

Within each period, engineering education evolved. In North America, the engineering program accreditation (ABET) criteria, for example, have stressed:

80's: Focus on bringing design into the curriculum again;

90's: Focus on non-technical skills (including societal and global issues, ability to apply engineering skills, group skills, and understanding of ethics and professional issues; and

00's: Innovation and creativity, new technical disciplines such as bio-engineering and nano-technology as well as understanding of societal and global issues and the ethics/professional issues.

Development of engineering science. On the other side, the development of modern sciences and engineering has made significant contributions to understand the physics that governs the world and universe, especially the forces or interaction potentials of nature (macroscopic and intermolecular)[3]. More understanding of applied physics (e.g. forces) leads to the desire of controlling the operative forces for applications in engineering and industries. Science always takes the lead far ahead over, powers and transforms manufacturing industries in the last centuries. In 20th century, three major areas of research for physics of forces or interaction potentials, i.e., forces acting between simple atoms and molecules in gases [4], chemical bonding between ions, atoms, and molecules in solids[5], and longer ranged interactions between surfaces and small "colloidal" particles suspend in liquids[6,7,8]. The rich deposits out of the scientific advances (such as Newton's laws, thermodynamics, statistical mechanics, molecular structures and forces, quantum mechanics, and mathematical and computational tools) continuously provide nutrition for applied science and physics to power engineering science, which further transforms manufacturing.

For a long time, the fundamental knowledge paved the way for all applied science and engineering physics, rippling forward to advance manufacturing processes for metallurgy and materials processing, chemical engineering, semiconductor devices, and transportations etc. The review of scientific advances in the fundamental levels suggests that the modern scientific framework (e.g. quantum mechanics) reached its peak in late 1950s. Afterwards, most of scientific activities were more focused on the applied sciences due to a lack of revolutionary advances in the very fundamental level. In the meant time, fuelled by significant breakthroughs from applied sciences, manufacturing activities and productivities reached an unprecedented level in human history. Research on

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manufacturing science and engineering also flourished, as shown in Figure 1[3]. As manufacturing precision progressed to micro/nano scales, applied science plays critical role in both science domain (for proving/validating and even further developing the science theory and principles) and engineering domain (for better developing, control and even understand of the various new processes). This requires the engineering professionals to have stronger science background, not only the knowledge but aslo the way of thinking, than before. The conventional engineering education system needs to be reformed to better support this change.

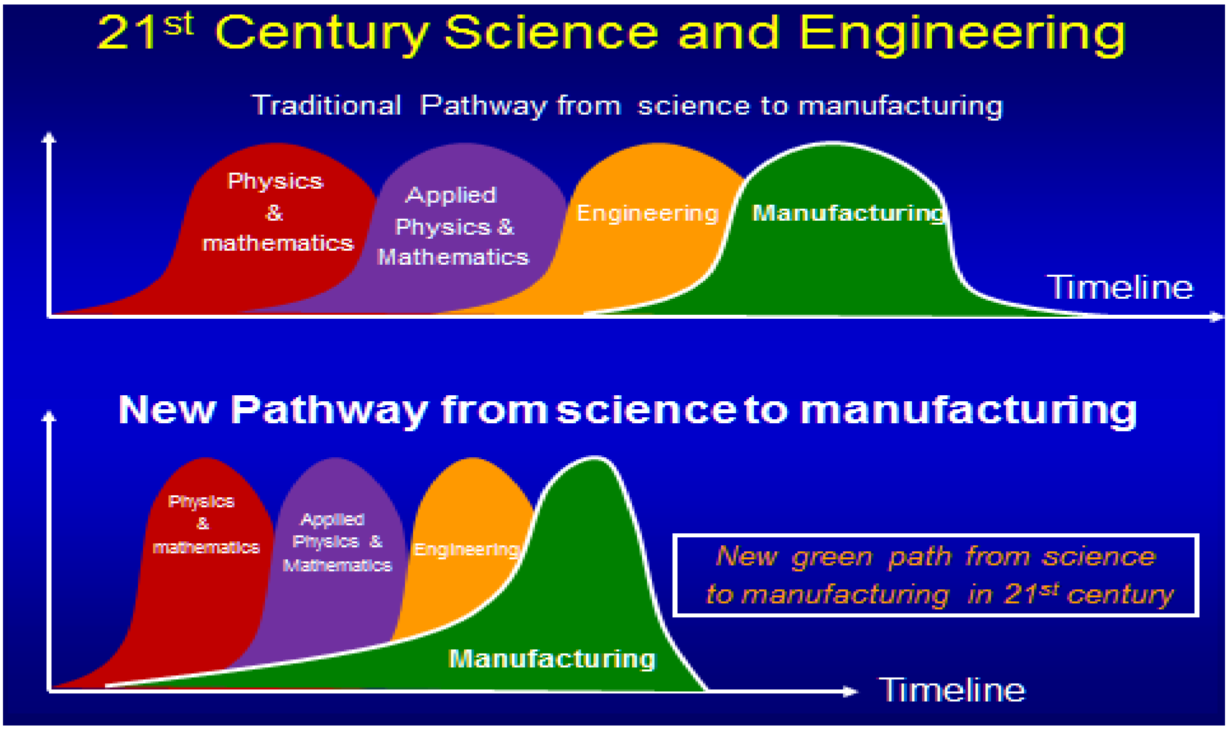

Figure 1. The development pathway from science through manufacturing

Engineering education. Engineering education needs to accomplish two objectives[9]:

- Teach the students what engineers need to know (e.g., statics, solid mechanics, thermodynamics, etc.), to become an expert in the major by learning the discipline, mastering the content, and getting the answers right.
- Have students start to think like engineers (e.g., to design, be creative, understand the need, long and short time cost, social and environmental impact, communications, professional ethics, etc.), to learn how to solve real problems, to master the process, and to ask the right questions. It is very un-disciplined. It is about learning and courage. It is about getting the job done and know how to get the job done.

With the IT and other capability developed, it is possible for entrepreneurial engineers to

- Know everything largely by being able to find any information quickly and knowing how to evaluate and use those information;
- Be able to do anything by understanding the basics to the degree on what needs to be done and acquiring the tools and collaborators needed;
- Work with anybody anywhere through using the communication skills, team skills, and understanding of global and current issues to work with other people; and
- Imagine and make the imagination a reality based on the entrepreneurial spirit and the managerial skills to identify needs, come up with new solutions, and see them through.

Volume of knowledge and integrated knowledge. At the time of knowledge explosion, the traditional classification of quality engineering professionals as generalist or specialist may not work, particularly under global economy. For quality professionals in the new era, it is required to have significant uniqueness and broad view of the knowledge so that it is possible to know who to collaborate and to be identified as a collaborator. This is part of the education goal as listed above, but from a different angle. Figure 2 shows the concept of the knowledge structure change[10].

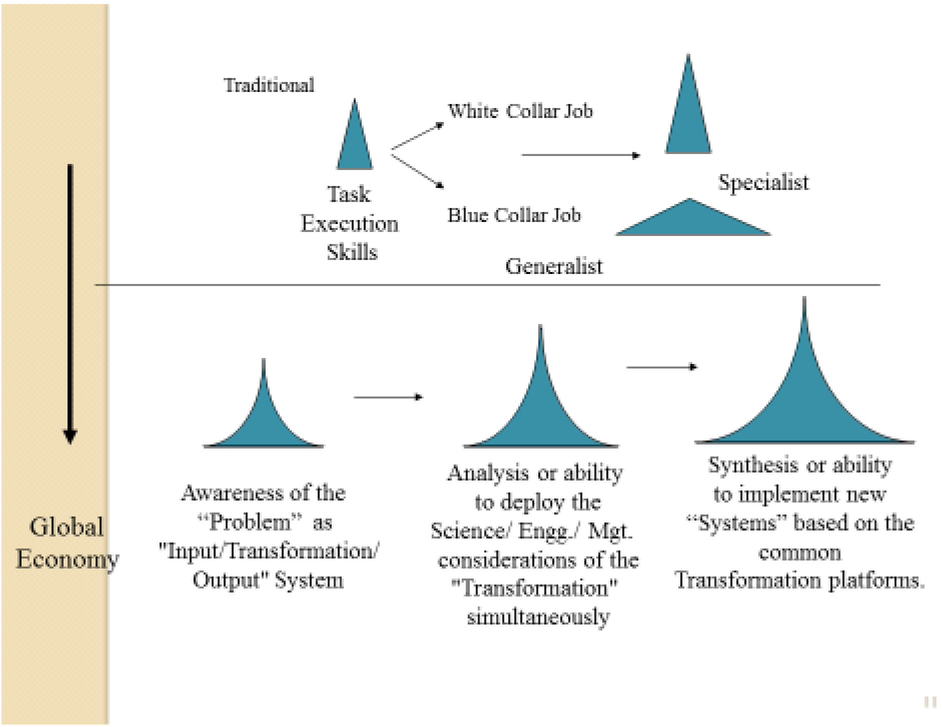

Figure 2. Knowledge structural change

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2. Challenge in Current Curriculum

In most of colleges in China, the students are organized into "classes" where those in same major will spend most of the time in four years together, taking almost the same courses. Although the curriculum has been carefully designed and a lot of effort has been put through to improve, the change is limited due to a lot of constraints in the system. There are not much chance for students to change major and not many choices to select different courses based on personal talent and interests, partially because the core courses are only offered once a year. The students have to take the core courses in the specific semesters and the percentage of the so defined "core courses" is very high, leaving little room for elective courses.

On one side, more in-depth courses, particularly the fundamental science courses, are needed to catch the rapid development of engineering science. On the other side, more courses and practice on entrepreneur/innovation are desired and encouraged in order to bridge the gap of academic research and industrial applications. Only limited credit hours are available in four years. Also you may not expect a quality graduate becomes a famous scientist and a successful businessman at the same time.

In current curriculum, almost all students are required to master "all content" specified in the core courses and expected to become the same or similar "experts" in the field. However the fact is that a large percentage of the college graduates may not work in the field and/or even not on the technical roles, when or soon after the graduation, although the college education is still very important and beneficial. They have to learn much more new knowledge, skill, and even the way of thinking in working places, particularly in the beginning. Although it is the problem everywhere, we at Tsinghua University have recognized the urgent need for the change to adapt to the fast changing world and for our graduates to have a better start of their professional career, benefitted from their college training.

Tsinghua University has excellent undergraduate students body, among the best in China. The variety of excellent graduates is demanded in job market and a flexible curriculum is needed to let them grow based on their talent and personal interests, as well as the market need. However, a few relationships need to be balanced between, 1) the basic academic requirement and flexibility of personal development, i.e., required core courses and electives from personal interests; 2) technical skills and personal creativity; 3) knowledge and ability, e.g., volume of knowledge vs. integrated knowledge, and ideas vs. skill/functions; 4) courses vs. practices/projects; and 5) science/engineering knowledge/skill vs. non-technical skills, such as teamwork, leadership, and communication.

3. Curriculum Design

An experimental class was chosen to implement a new curriculum, slightly deviated from the regular curriculum, to enhance the flexibility and facilitate the variety of quality graduates. Figure 3 shows the four year plan of the curriculum.

The curriculum is roughly divided into three modules, i.e., 1) basic science and social science/humanity (GE: general education) courses, 2) engineering fundamental courses,

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and 3) professional disciplines (major) courses. This is the same with most of other schools and regular classes. The challenge is to make it flexible to individual students.

On the other hand of teaching methods, it is also divided three categories, i.e., 1) course study, 2) planned experiments and practice, and 3) self-guided practice. The last one is new and intended to facilitate/encourage innovative explorations beyond regular curriculum.

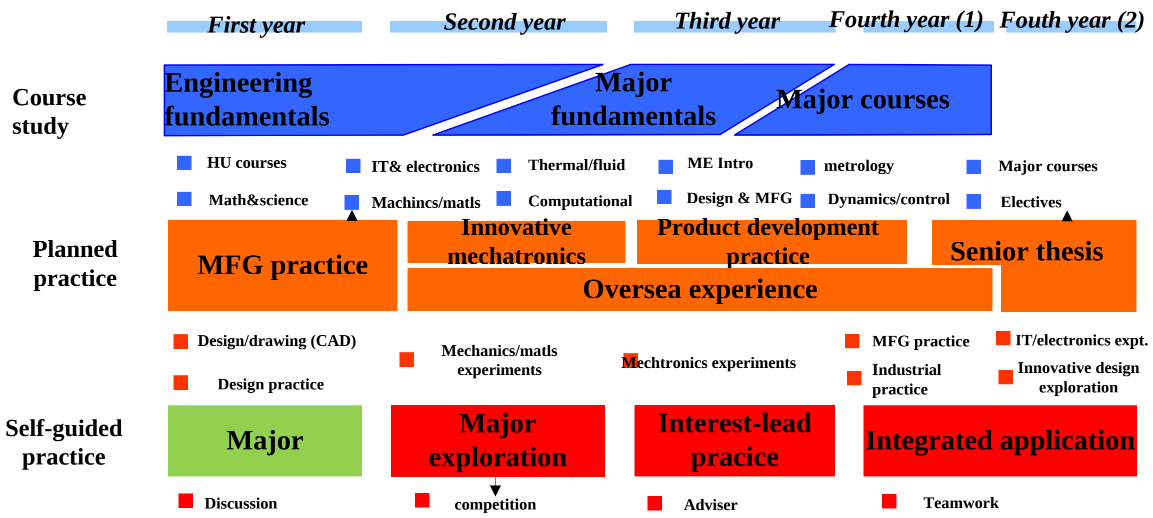

Figure 3. Four year plan curriculum

Main features of the new curriculum include the following.

1. *Fundamental emphasized to respond to the challenges in engineering science.* Our design is not to offer or design new and more in-depth science courses particularly for the experimental class. Instead, the students are encouraged to take such courses in other majors. These courses are in groups for easy substitution of requirement satisfaction. For examples, it is encouraged to take mathematics course with math majors and physics courses with physics majors. It is determined based on personal talent/interests and consulting with the adviser, i.e., not all students are choosing the same courses in the class. The challenges include, first, when you choose a course with the students in another major, you need to devote more effort than normal time to achieve satisfactory grades. Secondly the course content may not match well with regular course content other students in the class are learning. Then when you are learning proceeding courses, some content needs to be picked up on your own. It is not emphasized on the volume of knowledge, but the way of learning and the integrated knowledge. Our opinion is that for top students, they should be able (or get used to) work/study with incomplete knowledge and they should have had the ability to learn the required content of knowledge on your own since they have the necessary training on the subject, particularly the understanding of

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the discipline framework. Another important benefit is to learn the way of thinking in science more than in engineering.

2. *Mechanical Engineering oriented*. Two new courses are under development. They are Design and Manufacturing Fundamentals 1 and 2. With the courses, the students should go through a complete design (production development) loop. The components may include design using modern materials and advanced manufacturing technology, integrated design of complex systems (e.g., coupling with thermal, materials, mechanic, electric, analysis, as well as sensing, signal processing, and actuation), digital design and optimization, visual thinking, and innovation/management issues. After taking these two courses, the students should be well prepared to learn more advanced subject in their selected disciplines. The students are not necessary to choose same major disciplines as before while keep a sound fundamentals in Mechanical Engineering.

3. *Equal emphasis on course study and engineering practice.* The curriculum is such designed that the three tracks of flow progressing together through the four years. The course work is divided into three modules as stated before. The required/guided practice includes cognitive process, skill training, and research exploration within the normal credit hours, as well as course projects for juniors and seniors. Again the practice activities can be substitute with different options. Examples are conducting projects sponsored by different companies and studying abroad as long as justified to satisfy the academic requirement. Besides, a self-guided practice is added as a loosely required activity to provide an innovation platform for students working on their own idea, including academic, technological, and entrepreneur explorations.

4. *Globalization*. The students are required to participate international study activities, which could be course study and/or project work at a foreign university, or project work working with foreign students on real world problem solving. The school will provide opportunities and resource to facilitate these activities. The global thinking and non-technical skills (societal understanding, communication, teamwork, and leadership, as well as professionalism) are particularly emphasized in the activities.

This is an on-going process of the new curriculum design. It will be modified during the implementation. More case studies are on the way and will be presented in near future.

4. Summary

This paper mainly introduces an experimental design of a new mechanical engineering curriculum to enhance the flexibility of selecting courses and practice activities. The design is based on an analysis of the new challenges brought from the industrial and engineering science development. The change made to the existing curriculum is to emphasize on providing opportunities for talent students to develop their own capability uniquely and differently, while self-learning and integrating knowledge into real applications are the baseline. The exploration is on-going and more case studies are on the way shortly.

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Distance Learning, E-learning and Blended Learning

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Developing E-Learning Models of Multimedia Instructional Design and Implication for Special Students

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Abstract

The content of this project is utilized from "National Digital Archives Programs, Taiwan" (NDAP) where offers the organizing and assessing E-Learning Models of Multimedia Instructional Design and Implication. We make the digital teaching material match the actual teaching demanding, develop, and study the tactics and ways effectively to focus on the unit of "Water Circulation" of "Environment and Life Science and Technology" for K-12 school courses. We develop several teaching materials and the content "Going to the Toilet by Oneself" for the disable students of special education to assess the teaching effect via the seed teachers, and try to set up the studying-type community.

This paper will propose to make the procedures concretely, to demonstrate them in the digital content, and to discuss the assessed effects for E-Leaning.

Keywords: *digital learning, Multimedia Instructional Designs, E- Learning. ASSURE, ADDIE*

1. Introduction

The digital learning has been the best way to decontrol the limits of space and time and to improve the teaching materials. In that case, people all over the world emphasis much more on digital learning. Besides promoting several nationwide digital learning projects, Ministry of Education of Taiwan will construct digital learning environment and set up as one of the main shaft working projects. (Calculating Center, Ministry Education, Hu, 2001). The course goal of "Environment and Life Science and Technology" relies mainly on training students' scientific and technological accomplishment ability which is to cultivate the cognition via scientific, technological knowledge and solve the problems effectively so that it becomes the basic teaching goal of "Environment and Life Science and Technology" (Xiao Ting Zhang, 2002; Yang ShuQing, 2000). In recent years the auxiliary teaching method through digital learning has been discovered to improve the special children's cognitive obstacle. Digital learning can use the computers to communicate with the special children who are poor at speech and communication. This discovery makes the methods of special education more various. The forming of digital learning is to build and to construct its unique knowledge system by learner's independent study (Klapper, 1997; Lyons, Hoffman, Krajcik, & Soloway, 1997). It shows the digital learning can help special students to learn in the correct and suitable teaching ways for individual. Therefore, this project implementation is mainly for students to learn how to study and explore in the way of digital learning. By the lively experiment games, we turn the original difficult content of studying to become enriching and interesting learning.

2. Developing and process of the project

The researchers, matching the model “ASSURE” (Heinich, Molenda, Russell, & Smaldino, 2002), guarantee to design and use the teaching media effectively. ASSURE model emphasizes on designing the teaching media for actual usage; this model includes (1) **Analyse learners**: including students' general characteristic, concrete starting ability, and learning style. (2) **State objective:** describing the teaching goal can be derived by the course outline. (3) **Select instructional methods, media, and materials**: choosing the media and teaching material: Set up the bridge between learner's starting behavior and the teaching goal. (4) **Utilizing media and materials:** using the media and teaching material: Carry on the teaching material suitable and decorating the teaching environment. (5) **Require learner participation:** arranging the activities for the learners having a chance to participate in. (6) **Evaluate and revise:** Comment the influence and result and measure the teaching.

After “Environment and Life Science and Technology” of middle school teacher's interview investigated by researchers, it is found that most learners fear to study this subject, may not repel naturally, nor catch up with the teaching process. If the teachers just adopt the lecturing type, such traditional ways certainly will be dull and tasteless (Shi Hwang Hong etc., 2004). According to the special characters of the disable students, teachers must be patience, and think about the simple affairs in various ways through multimedia contents to help special students to learn. Unfortunately the workshops of multimedia teaching materials designed for special students are actually rare now.

According to Heimlich’s designing theory foundation (2002) about teachers’ actual demands, this project completes the designing process including the teaching plans writing and the content of digital learning including the on-line question sheet and zone of discussion, and etc. We hope to carry on the digital learning and help the general students and special students to learn for k-12 education.

1. Writing the teaching plan:

In the first theme of " Water dripping water in Taiwan” the learners of middle school will learn the ternary circulation and water pollution and the other theme is "Go

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to the Toilet by Oneself." for special disabled students in middle school. Since a successful study can effectively initiate students' forming and construction of the course. (Qiu QiongHui, Wang ZhenChuan, Zhang TengYuan, Chen HuanBin, 1998; Lee & Midkiff, 1997), this project adopts digital learning for the main shaft, natural science as the background, and environment education for students. Cooperating with the on-line evaluating system, we make the enriching and interesting evaluations in order to reach the teaching goals we expect.

2. Appearing the content of digital learning

The content of digital learning contains two major parts: website teaching and multimedia instruction.

(1) Website teaching construction. (See Figure 1 and Figure 2)

Besides offering and looking up information, it helps cooperative learning in two-way communication discussing. This website allows teachers and students use computer and Internet to play simultaneously with the synchronous on-line and asynchronous teaching activity and create an environment that can learn and support the teaching (An Qi Yeh, 2000).

Figure 1. This project website's organic structure framework design drawing. (Source of design picture: by Wei Xin Liu, 2004) URL: http://chuang.yuntech.edu.tw/nadp/

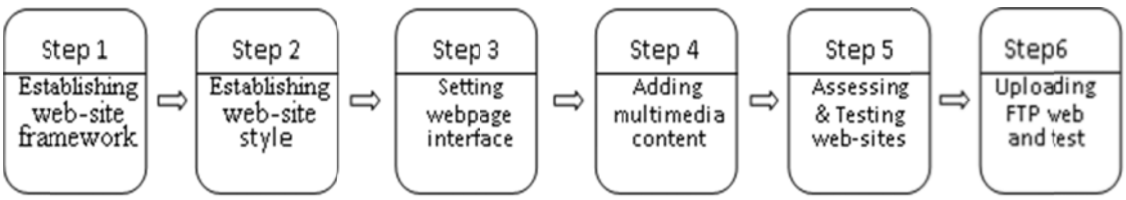

Figure 2. The webpage of "NDAP" in Taiwan e-Learning and Digital Archives Program URL: http://teldap.tw/index.html

This website offers a good learning environment for learners who must register as the members of this website. To enable users to understand it, the contents of this website use Flash animation technology and provides the characteristics of multimedia such as Chinese characters, pictures, cartoon, sound, images, and etc. (see Figure 3 , Figure 4, and Figure 5) It is inter-dynamic with the on-line discussion teaching material according to the student’s concept of participation to guide the learning with the multimedia cartoon materials step by step and to offer the education resource of teaching materials of network education resource correlated with courses.

Figure 3. The teaching webpage of “Water dripping water in Taiwan", the water droplet baby was voted by students.

URL: http://chuang.yuntech.edu.tw/nadp/Water-index.htm

Figure 4. The teaching webpage of “Special Education"

URL: http://chuang.yuntech.edu.tw/nadp/Special-index.htm

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Figure 5. "Go to the toilet by oneself" teaching webpage.

URL: http://chuang.yuntech.edu.tw/nadp/Special-01.htm

URL: http://chuang.yuntech.edu.tw/nadp/NDAPSite1111/index.htm

This construction of teaching websites is made by the ideas and model of systematized teaching designs. First, we analyze instruction goal and demand as well as the restriction of websites. Second, we analyze the content to confirm the teaching theme, and collect the suitable teaching materials. (Shen Zhong Wei, 1998) Third, we set up main structures, program the webpages. Forth, we test the website. Lastly, we implement and evaluate the effect of auxiliary teaching of course webpages on-line. The system can count scores automatically to feedback the learning effect in time, and display which part to strengthen therefore the teachers can look over the testing process and provide further guidance. The website helps learners at any time to learn by oneself, to improve the learning effect, and to set up the attitude of lifetime learning. (Liu Wei Xin, 2005; Wong, 2000)

(2) The multimedia instruction design

The multimedia instruction has offered and leaded learners to the new learning experience and to learn independently. The ability of simulation enables learners to learn by computer tutor and to set up the foundation of abstract things. (Lin Shu Fang and Lin Li Juan, 1995; Hong Rong Zhao, 1992; Ho Rong Gui and Guo Zai Xing, 1997; Xu Hui Qing, 1994).

This project is designed by systematized teaching (ISD) and made it the computer multimedia teaching materials. Designing systematized teaching goes through the factors of the inter-dynamic teaching related to the overall course. We make the most advantages of this method to develop various kinds of models, including the five phased procedures, analysis, design, development, implementation, and evaluation and taking reference tools of ADDIE (Dick & Cary, 1996). The application of computer multimedia includes teaching-type learning (see Figure. 6 and Figure. 7), practicing again and again, playing games, solving the problem, and etc. Therefore, this multimedia project also provides learners to do learning activities, including cognitive learning, learning by theme and cooperative learning. In this way, this project enables learners to probe into and find out the problems, to cooperate and learn what this website offers to link, to actually search the relevant learning contents deeply. The evaluation of the learning effect will carry on network interactive evaluation, forming evaluation, and summing-up evaluation, and matching learning process of learners. Here is introducing the learning ways: (1) Cognitive learning: the learnersactively read relevant learning resources on the websites by browsing and checking the learning content. By learning by one-self, the learners peer learning, andteacher-student learning. We make the on-line tests and learning by searching in order to evaluate the learning effect so as to obtain “procedural knowledge” and “strategic knowledge”. By activities of interactive discussions, viewing, and cooperative learning, students can build the “constructive knowledge or meta-cognitive knowledge.” (2) Learning by theme: The characteristic of the theme-type network course structure via the course discussion, and integrating various ways of different subjects, enables learners to discuss together, then to find out the answers and effectively use learning websites of this project to finish this teaching network multimedia activity. (Lin Yi Hong, 2000). (3) Cooperative learning: The system functions provide information sharing, group-type data dealing, discussion, viewing, and etc. It makes teachers and students easily do cooperative learning activities. (Wang Chien Hsing, 1999; Wang Shu Ru &Wang Yu De, 2001)

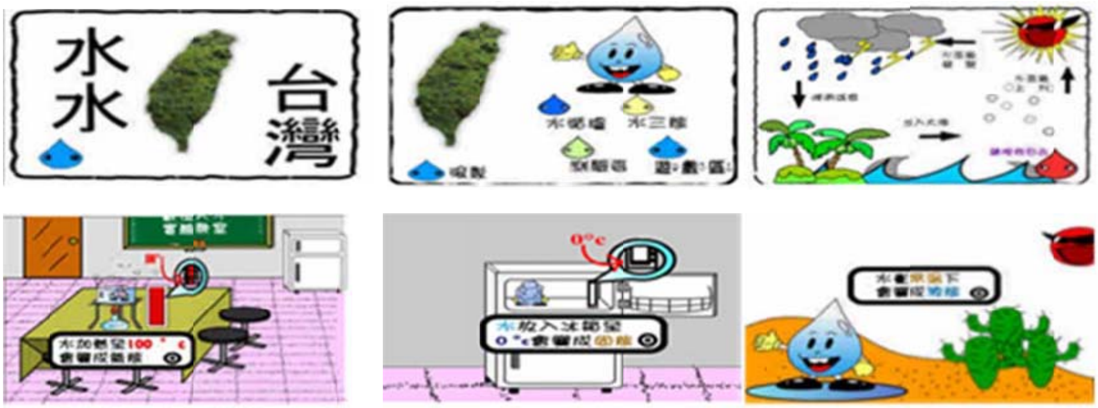

Figure 6. the tractate of water circulation and water for the teaching type.

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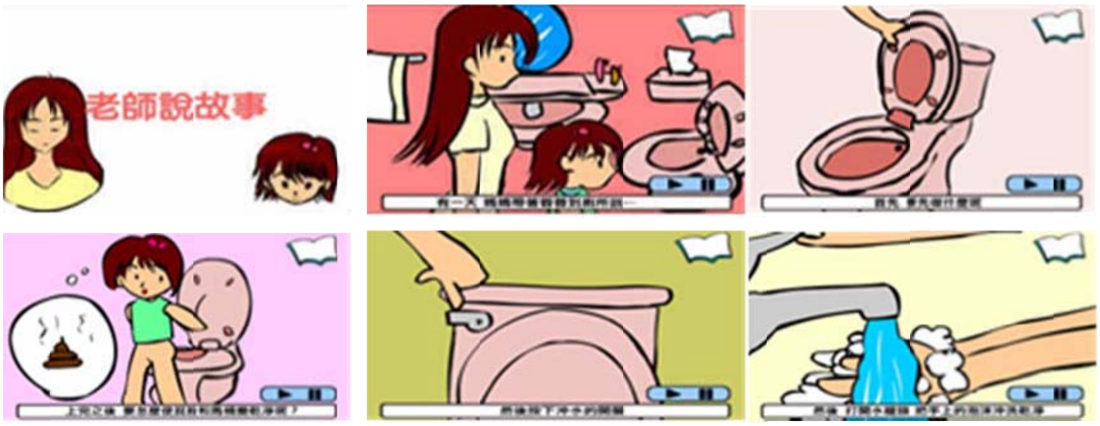

Figure 7. The unit that the teach r tells stories - present the steps that go to the toilet with the teachin type

3. Results

1. The research shows 90 students of the middle school including 33 of class "A", 28 of class "B", and 29 of class "C" uses 200 minutes teaching time of ten questions focusing on the starting behavior for pre exam. After that, the teachers tell them about the content and what the knowledge they'll obtain. Then teachers make teaching multimedia materials taken by video recording to inspire students to do in daily lives. There are 25 questions in later exams including ten questions in the starting exam. The exam outcome is for the teacher to check the teaching effect, and students' learning result. Students can ask the questions if they don't understand on-line, meanwhile all the teachers and classmates can respond at once.

The result of exam **(see Table 1)** shows that class "A" gests better starting behavior and better learning ability but class "C" students' progressing rate is the highest. The 90 students have accepted the attitude research. It shows 96% all think it is very helpful; 75.4% think they can learn more i formation than in traditional teaching; 93.1% think this learning way can stre gthen their learning motivation. As for the form of the webpage, all the student think the design is pretty good and the arrangement of the vision and figures is very go od; 86.6% think the association of information is very appropriate; and 87% think the content of the project is easy to understand.

Table 1. the result of the starting and later exam

Learners of being examined	Rate(%) of right answer in starting exam	Rate(%) of right answer in later exam	Rate(%) of progress
Class A	**72.4**	**85.1**	12.7
Class B	63.3	76.8	13.5
Class C	61.4	77.5	**16.1**

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2. Implementation of the course and the result of "Go to the Toilet by oneself".
By two hours of teaching time, the samples are divided into two groups of "Go to the toilet" and " **Wash the hand**". **(See Table 2)** The experimental subjects are the intelligent-retarded students in middle school in Tainan. There are 8 including 5 multi-obstacle ones, and 3 intellectual-obstacle ones, of obstacle degree by 1 medium-degree, 3 heavy-degree, and 4 extra-heavy degree **(see Table 3)**.The analysis shows there're 4 of 8 students (students 1, 2, 4, 7) making progress. These students in starting exam have shown the abilities of going to the toilet by oneself (45%, 15%, 20%, and 50%). Repeated practices by digital teaching materials will strengthen the ability. In the unit "the teacher tells stories,"**(See Figure 5)** the teaching material firstly explain how to go to the toilet step-by-step. The teacher can suspend the screens to test the learner's cognitive ability immediately. This software design, according to the cognition theory Gange (1992), not only focuses on old enhancement of knowledge, but also makes detail new knowledge teaching for the disable.

Table 2. the observed items in the starting and later exams

Group1. steps: Go to the Toilet	Group 2. steps: Wash the Hands
1.Knock at the door before going to	1.Use water to bedew hands at
2.Close the door after entering the lavatory	2.Rub the fingers with the hands and mean that sews while washing
3.Going to the toilet meanwhile putting down the nights tool to cover	3.Can use water to wash hands clean while washing hands
4.Going to the toilet and taking off the trousers (the pants and other trousers)	4.Will hold water and wash the faucet while washing hands
5.Going to the toilet and sitting on the	5.Can use the towel to wipe hands
6.Going to the toilet and clearing up a messy situation to settle an impasse	
7.Going to the toilet and washing by	
8.Putting on the trousers after going to	
9.Washing hands after going to the toilet	
10.Wiping hands after going to the toilet	

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Table 3. the result of starting exam and later exam

Later exam	Starting exam	Obstacle degree	Obstacle types	Age	Gender	learner
60	45	Extremely heavy	Multi	10	male	1
20	15	Heavy	Multi	10	female	2
20	20	Heavy	Multi	8	male	3
25	20	Extremely heavy	Intellectual	10	male	4
0	0	Extremely heavy	Multi	10	male	5
25	25	Heavy	Intellectual	11	female	6
70	50	Medium	Intellectual	10	male	7
0	0	Extremely heavy	Multi	9	female	8

4. Conclusion

The characteristics of the multimedia teaching of this project contains: interaction, individualization, versatility, and motivation. In the project, we focus on teaching the ways step by step, repeatedly, demonstrated patiently. Though the analysis can't solve all problems for all the special children, this project can offer the teachers for the reference of new teaching ways and concepts.

With the constant development of science and technology, many new auxiliary media of digital learning may take shape in the coming future. A teacher is still a main provider source of the teaching information, and the media is only the transmission tool only. Therefore the choices of digital learning ways must match what the teacher wants to teach and design for the course. To choose and to use the suitable learning platforms will assist teachers more effectively in the class.

5. Suggestions

Here we describe the difficulties we encountered and the solutions we used to give the reference for the later researchers. First, the planning members are not familiar with writing the script or with the sufficient creativity. Second, the production members are lack of animation programming ability, spending too much time in editing contents, and the difficulty of the implementation due to the poor equipments in the school. Lastly, the project leaders, the enterprise planning manager and the animation industry personage are so busy that the project members, all students, are in the slow project processing with lack of experience.

The solution is to use the MSN and Skype to communicate with each other. We write the form of the discussion script, lead the creativity to extend, and encourage members to develop by the clockwise circulation type to excite the intention. Although this way is time-consuming, it can reply the problems and answers in time. We note and store the relevant records after attending every net communication and they save a lot of time for completing the work.

Moreover, we encourage the project members to enthusiastically participate in the training programs, and to improve the producing ability and to benefit a lot. From the teaching plans and intention script of animation making, it does not cost much time to make the digital content but needs more improvement in the future spreading and commercial usage. We indeed need to go on simplifying and making the necessary standardization of each item in each step of analysis, design, development, evaluation, and etc.

There are a lot of problems while implementing this project; for example, the computer speed is very slow, the network is unstable, the teaching material resources are insufficient, the teaching time passes by, the preparing lesson is too long, and etc. Any of these factors will influence the teacher's teaching will. The more factors are improved, the more students' learning interest and the teaching will of the teachers' will be improved.

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Exploring the Internet of Cooperative Learning Groups Using Content Analysis on Cohesive and Collaborative Tasks in E-Learning System

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Abstract

This study purpose was to explore the Internet of Cooperative Learning Groups using Content Analysis for Cohesive and Collaborative Tasks. According to the study samples of graduate students attending “Comparative Vocational and Technological Education course“ at Graduate School of Vocation & Technological Education, National Yunlin University of Science and Technology, T-University in Taiwan. There were 23 graduate students in class, divided into six cooperative learning groups using instructional materials and activities via e-Learning system that was using the Internet as an academic instructional platform. During the class, there were five times of students coming to class face to face, eight times in synchronous learning ways, five times in asynchronous learning ways. Using the Internet online and real time ways for discussion groups, the anticipants shared the course contents, and panel's reports with each other. For reference of content analysis of "Students online discussion Dialogue WPBL" cooperative task model of Tsang Kwok-hung[12], the study method defined respectively problem determination, recognition and discovery, planning, alternative, dialogue type construction and evaluation for early the fourth week, mid-eighth week, the end of 15th week in the conversation contents. Comparing to each group, the study analyzed the Internet cooperative learning groups to discuss the distribution of dialogue situations and the total number of dialogue cohesion.

Keywords: *Internet cooperative learning , Cohesion and collaborative task , Blended Learning*.

1. Introduction

In 1997, Minister of Education (MOE) in Taiwan embarked on promoting the distance learning course with synchronous and asynchronous teaching. Besides, in 2006, MOE announced the rule for practical college distance education, conducting the course with digital learning. Under the credit-based and the digital material mechanism, the Executive Master of distance degree had been set up to make people increase their self-growth via digital learning and to reach the purpose of lifelong learning[9]. This kind of digital learning not only provides multiple approaches but reduces the negative effect of region and time problems to enable the learners process and interact with the curriculum design through the internet to gain more accessible teaching materials, such as the videos on the internet platform. Consequently, digital learning has been commonly applied in the education field in Taiwan.

1.1. Purpose and Motivation

In the era of advanced information technology, more and more educators utilize the characteristics of information technology to inspire and guide students’ learning. It’s a supporting tool for teaching, information technology ignites students learning interest and motivation. No matter what kind of the teaching method you adopted, teaching with information technology would undergo five basic steps: pre-preparation, introduction, development, integration, and after-class learning.[8] However, if learners only used computers they were unable to ask teachers instantly or discuss with their fellows whenever they have questions. Sometimes this situation leads to a decrease in learners’ learning interests[3].

Therefore, the researchers adopt multiple teaching methods to assist learners construct their knowledge[8,1]. In this way, learners could use the internet platform as the medium of online discussion, process the group

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discussion on the web cooperative learning, brainstorm and share the knowledge and express suggestions by means of interactive communication. After the leader lead the group member to discuss the content and reach the goal together. Was there any influence on team cohesion that result from the leader? How to employ the online discussion to make learners arouse their learning motivation, increase the academic knowledge and facilitate the interaction and communication efficiently. According to Tseng's[12] research on analyzing college students application of Web Project-Based Learning (WPBL), the interaction between college students includes general explanation and unconstructive knowledge for the most time, put some novel idea or revise the question, express their own reflections in detail belong to high level cognitive ability. Thus, students seldom adopt and use high level cognitive ability to overcome those difficult and complicated problems while they had dialogue in WBPL. This study employs Tseng's[12] cooperative task model to analyze the discussion that students at T university of science and technology. With the group discussion, curriculum and report were conducted in this classroom. Cooperative task model contains problem determination, recognition and discovery, planning, alternative, construction and evaluation dialogue type. The purpose of this study was to examine students' conversation when using cooperative online system and compare the total number dialogue among each group. The research method focuses on early fourth week, mid-eighth week, the end of fifteen week in students' conversation.

1.2. The Restriction of This Study

The participants of students were at T university of science and technology which is located in Taiwan taking the course '"comparative vocational education"' were invited in this study. The study aimed to investigate participants' satisfactory on using the internet learning platform. The most significant factor was students' dialogue type; second factor was the settings of the internet platform. Due to the limited time and concept aspects, That meant that the restriction for the sake of geographical and subjects limitation. Therefore, the result of the study had difficulty referring to other cities or universities. In the mean time, inn this study, impact from other social factors were not discussed.

2. Literature Review

2.1. Web Cooperative Learning

Compared with the traditional learning mode, cooperative learning has different environment and activity. In the traditional learning, teachers attempts to control all the things without emphasizing the cooperation among students. While the in cooperative learning settings, teachers act as a facilitator because the students need to be active in the learning process. Students were responsible for leading as well as cooperation by themselves. Teachers would proceed the group discussion based on student's gender and different levels.[2] Through the encouragement, communication, explanation, analysis and demonstration, students in this cooperative learning increased their interaction with their group members. This enhanced students' learning ability in terms of their learning attitude, motivation and problem-solving, and academic ability. Hence, adopting the web cooperative learning was easier to achieve the goal in learning [10]. [2] Chen suggested that there were five efficient cooperative learning elements:

a) **Structure of the group:** the size of the group, the characteristics of the group and solidarity.
b) **Task Cooperation:** ask the group member to complete the task encourage.
c) **Induction Cooperation:** set up the incentive to cheer
d) **Individual Responsibility:** offering the awards/encouragement according to the completed task in case someone did not want to participate.
f) **Settings Cooperation:** providing specific space for students to discuss and learning.

In this study, web cooperative learners used the E-seminar platform, either the synchronous chat room or asynchronous discussion room, to share, talk about what they had learned in the classroom, and make the reports.

2.2. Interaction among the Group

The leaders indeed played significant roles in this internet course [5]. In order to lead the whole issue, leaders needed to take care of every group member and pose the key point or issue. If the group member was hard to follow, the leader should ask someone to answer or make clear the topic once again. If anyone disagreed the topic, the leader should try to go back to the track. In fact, leaders acted as arbitrators because they had to choose the suitable program. In the meanwhile, during the discussion, leaders cheer for the group members continuously. Unity stands for reflecting the goal that group member during the dynamic process [4]. When the group member had highly cognitive influence, the more unity they had with more efficiency. This unity had impact on the consensus because of activity, goal, experience, the clearance of task, feedback and time [8]. As a result, the importance of the leader was obvious because the leader should guide the members whenever they use the E-platform.

2.2.1. Cooperative Task

Cooperative task model that Tseng[12] pointed out contained problem determination, recognition and discovery, planning, alternative, construction and evaluation dialogue type. Dialogue type included **General explanation**: explain unconstructive idea or knowledge. **Organization:** organization comes from the books, website and other source. **Citation:** Cite directly from other sources. **Brainstorming:** add novel idea. **Problem-Solving:** provide the fault explanation. **Reflection:** express the feeling and thinking. **Administration management:** arrange the meeting, do the report and monitor the schedule. **Unrelated stuff:** chatting. Furthermore, cooperative task model was defined as follows: P**roblem determination:** determine and point out the problem, R**ecognition and discovery:** find out the truth, useful information, P**lanning:** set the goal, revise the program, draw a structure of solving problem, A**lternative:** helps to yield new things, C**onstruction:** executive the plan, E**valuation:** test and evaluation. This study adopted Tseng's cooperative task model to explore the distribution of cooperative task via content analysis of dialogues.

3. Method and Design

3.1. Structure of this Study

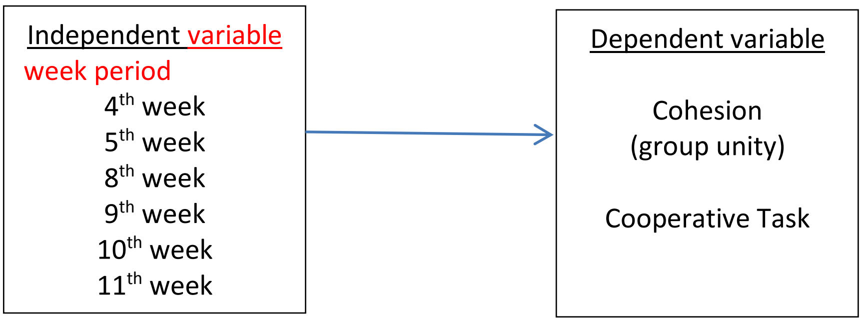

Figure 1. Structure of this research.

3.2. Participants and Research Tools

In this study, twenty-three students who took the course "comparative vocational education" in academic year 2012 were invited to join this study. Employ the cooperative task model in Tseng's[12] research *Online Dialogues of college students in a Web Problem-Based Learning (WPBL)* to analyze participants' content of the dialogue and to see the amount of dialogue among each group. Cooperative task model consists of confirmation, distinguish, problem-finding, planning, alternative, evaluation dialogue types. The experimental period lasts eighteen weeks, however, due to the midterm and the final exam that occupies 6 weeks, week fourth, week eighth and week fifteen were selected to be emphasized .

4. Data Analysis

Twenty-three students took the course "comparative vocational education". Group discussion through the web cooperative learning was conducted. All the participants were divided into six groups: group A with 2 people, group B with 4 people, group C with 5 people, group D with 4 people, group E with 4 people, group F with 4 people.

4.1. Introduction of the course "comparative vocational education"Participants and Research Tools

4.1.1. Instruction Objective

This course focuses on introducing the vocational education system of developed country. Comparative education was a gateway to an international viewpoint of diversity in education. Besides, how the comparative vocational education interacts with the economic and the industrial development was what we needed to think about. Instruction, group discussion, literature exploring, lectures and report writing were adopted in this course. After studying this course, students would be able to understand vocational education system of developed

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country, grasp the influence of the economic situation on vocational education toward the developed country, Compare the education system of developed country and identify its strengths and weakness of various education systems, and evaluate the trend of vocational education in Taiwan.

4.1.2. Syllabus

The course will be taught according to the syllabus and the students' learning outcomes were essential as follows:

a) The meaning and influence of the vocational education of developed country.
b) The background and the history of the vocational education.
c) The factors that vocational education influenced by industrial development.
d) The effect of occupational training certificate system on the vocational education.
e) Major issues like the challenge and the upcoming trend in the field of the vocational education in developed country.
f) Comparison and critical analysis on the vocational education systems of developed country.

4.2. Learning Manage System

In this study, E-platform at T university was used in "comparative vocational education". Let us see the table 1 below.

Table 1. Teaching and Learning Management

Instructors	Learners	System manager
1.browse the students' learning portfolio	1.browse the learning portfolio	1.the basic information manage about profile, course information
2.Statistical learning outcomes	2.look up the score	2.learning record, online discussion record
3.design,browsw and download the teaching material	3.online learning and quiz	3.collect the learners' historical record
4.manage and look up the score	4.online interaction with teacher or classmate	4.release and scan the latest news
5.perform various teaching activity .	5.online note-taking	

4.3. Distribution of Analysis Group and Task

This study stresses on online discussion circumstances of the week fourth, eighth and fifteenth on the basis of the most frequency and the least frequency to examine the effect group unity on the cooperative task. Figure 2 suggested that the situation of the week fourth eighth and fifteenth.

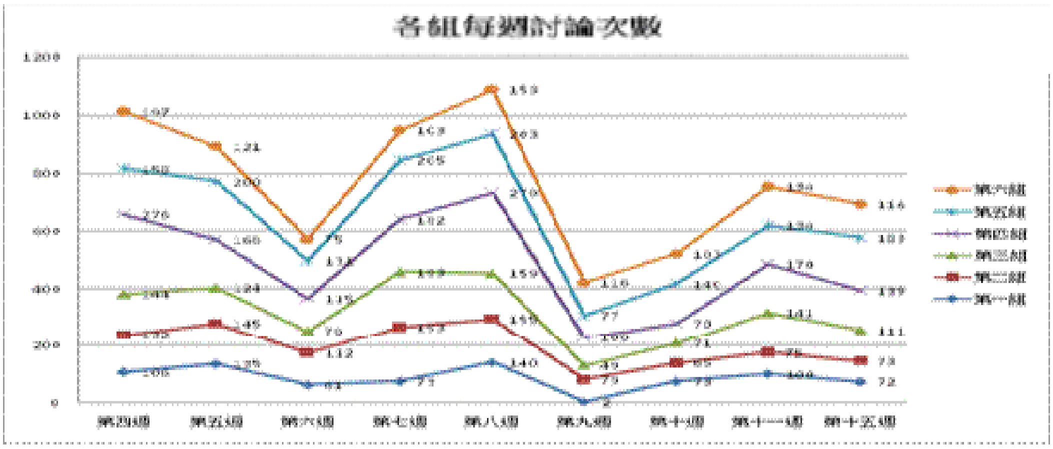

Figure 2. Discussion Times every week

In the early week fourth, it was found that group D has the most frequency on discussion (276 times). In this group, the leader guided and encouraged their members to answer the question by propose the question. In this way, the group unity could be increased. In addition, in terms of the dialogue type, recognition and discovery account for 92% (263 times). To analyze the content of the dialogue, discussing unrelated thing accounts for 29% (80times), explain and reply account for 22% (62 times), simply react accounts for 20% (30 times), asking short accounts for 11% (55 times), reflection accounts for 4% (12 times), analysis accounts for 3% (7 times), problem-clarifying accounts for 3 times and problem-extension for 4 times and administration accounts for 1% (2 times).
As for the planning part, it accounts for 23% (13 times). The explanation and reply accounts for 2% (5 times), administration and simply reply accounts for 1% (4 times for each). Furthermore, the problem determination accounts for 4% (9times) and others like simply react, explanation and reply, asking short and analysis accounts for1% (2 times), respectively. In the contrast, the group A has the least frequency (106 times) when the group

member discuss. This group contains 2 people only, the content of the dialogue occupy the most half in their dialogue, the group members were at equal position to discuss. It was, therefore, found that their dialogue exists almost in problem determination which accounts for 64% (69times). According to the dialogue type, explain and reply account for22%, simply react accounts for 10%, asking short accounts for 11%, administration accounts for 8%, discussing unrelated thing accounts for 5%, problem-clarifying accounts for 6%, others like general explanation accounts for 2%. Besides, recognition and discovery account for 30% (30 times). In the midst, explain and reply account for 9%, simply react accounts for 5%, administration accounts and asking short accounts for 4%, general explanation and discussing unrelated thing accounts for 3%, problem-clarifying accounts for 2%. The proportion of planning accounts for 6% (7 times), administration accounts for 5%, simply react accounts for 1%.

In the eighth week, as figure 2 suggests, group D still has the most frequency on discussion (279 times). In this group, the leader guide and encourage their members to answer the question by propose the question. By doing so, the group unity could be enhanced. In addition, in terms of the dialogue type, recognition and discovery account for 88% (244 times). To analyze the content of the dialogue, discussing unrelated thing accounts for 62% (172 times), administration accounts for 7% (19 times). explain and reply account for 6% (18 times), simply react accounts for 6% (16 times), asking short accounts for 3% (10 times), citation accounts for 3 times, problem-clarifying accounts for 1% (2 times), elaboration accounts for 1% (2 times) and analysis accounts for 1% (2 times). As for the planning part, it accounts for 12% (35 times). The explanation and reply accounts for 1% (4times), administration and simply reply accounts for 5% (15 times), asking short accounts for 1% (2 times), explain and reply account for 1% (4 times). In the contrary, the group A has the least frequency (140 times) because of the limited group member. It was found that their dialogue exists mostly in recognition and discovery that accounts for 100%. According to the dialogue type, discussing unrelated thing accounts for 54% (76 times), explain and reply account for 25% (35 times), simply react accounts for 16% (23 times), general explanation accounts for 2% (2 times), reflection for once, asking short accounts for 1% (2 times), and analysis accounts for 1% (once).

In the fifteen weeks, as you can see from the figure 2, group E has the most frequency on discussion (183 times). Leader in this group observed the interaction among their group members and share new knowledge with existing experience to raise their unity. The dialogue of cooperative task lies in recognition and discovery which accounts for 75% (137 times). Moreover, to analyze the content of the dialogue, discussing unrelated thing accounts for 41% (76times), explain and reply account for 21% (41 times), analysis accounts for 3% (5 times), simply react accounts for 2% (4 times), asking short accounts for 2% (3times), reflection accounts for 2% (3 times), citation accounts for 2% (3 times), organization accounts for 1% (once), problem-clarifying accounts for 1%(once). Secondly, planning accounts for 25% (46 times). In this part, discussing unrelated thing accounts for 10% (18times), administration accounts for 9% (16times), explain and reply account for 5% (10 times), simply react accounts for 1% (2 times).

Compared with the most frequency of discussion, group A remains the least frequency (72times) because there were two people in this group only. The dialogue of cooperative task mostly located in recognition and discovery that accounts for 100% (72times). The analysis of dialogue type was as follows: discussing unrelated thing accounts for 46% (33times), explain and reply account for 35% (25 times), reflection and simply react accounts for 7% (5 times), respectively. Others like analysis accounts for 3% (2 times), general explanation and asking short accounts for 1% (once).

5. Discussion and Conclusion

5.1. Discussion: Times of the period

Let us compare the discussion situation in term of the week fourth, week eighth and week fifteenth. In the early week fourth, according to the frequency of discussion when conducting the task, group D mostly located in recognition and discovery account for 92% (263 times). Further, it was found that the planning part accounts for 23% (13 times) and the problem determination accounts for 4% (9 times). While in the group A, their dialogue exists mostly in problem determination which accounts for 64% (69 times). Then, recognition and discovery account for 30% (30 times) and the proportion of planning accounts for 6% (7 times). In the middle week eighth, on the basis of the data from group A and D, it indicated that online discussion of the group D lie in recognition and discovery that accounts for 88% (244 times), and planning part which accounts for 12% (35 times). While in the group A, their cooperative task all goes to recognition and discovery that accounts for 100% (140 times). In the last period week fifteen, it was observed that the group E lies in recognition and discovery which accounts for 75% (137 times), planning accounts for 25% (46 times); as for the group A, while proceeding the cooperative task, the most proportion was recognition and discovery which accounts for 100%

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(72 times). The result shows that at the early period, online discussion of each group complete with problem determination, recognition and discovery and planning. As for the middle period, the recognition and discovery, planning and simply recognition and discovery were employed. Lastly, the final period suggests that the recognition and discovery, planning or simply recognition and discovery were used commonly to reach the goal.

5.2. Conclusion: Group Unity and Cooperative Task

The more cognitive influence the group members agreed toward the task, the more unity of that group obtained. From the record of each week in the study, the study showed that the most frequency of discussion were group D, E, F with four members in each group. Secondly were group B and C with four and five people respectively. The least frequency of discussion was group A. The mission that leaders had in each group indeed was crucially important. In addition to guidance for helping members to complete the task, leaders need to increase the interaction of each member by supervising, assigning and providing the knowledge or source. However, the diverse knowledge made the goal out of focus easily. Thus, it was suggested that leader was the key point in the web cooperative learning. There were only two members in Group A; ambition of achieving the goal was much stronger than others, though the sharing knowledge and source were limited.

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An investigation into the use of the Blackboard Learn Mobile App: An African perspective

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Abstract

Learning management systems, such as Blackboard Learn™, have become synonymous with higher educational institutions over the past few years in an effort to improve student engagement with course material and with academics. However, some students and academics of Blackboard Learn™ have criticized the system as being "technologically years behind", with an awkward, slow interface which makes basic tasks difficult to execute, while navigation within the system proves time consuming. Subsequently, Blackboard Inc. announced, at the end of 2013, that they had completely redesigned their mobile learning app after extensive analysis of how students use mobile devices for education. They claim that their updated version of the Blackboard Learn Mobile App simplifies content consumption which will lead to a more engaging user experience and greater productivity. The purpose of this study is to investigate these claims by determining to what extent students are using the Blackboard Learn Mobile App on their mobile devices while also obtaining their perceptions regarding the use of this app. There is currently very little scientific research available that can shed light on the use of this app within the African context. The target population is restricted to IT Students enrolled at the Central University of Technology in South Africa, where both quantitative and qualitative data was collected using a survey questionnaire as the data collection instrument. The results indicate that a large percentage of students are not using the Blackboard Learn Mobile App because the data costs are too high and their devices do not support the app. Some students are not using the app because they do not see the need to download the mobile app and are satisfied to use the desktop PC's on campus to access Blackboard. The usability study of this app revealed several problems which are currently encountered by students with regard to watching YouTube videos, posting replies on forums, doing assessments and submitting assignments.

Keywords: *Mobile learning, Learning management systems, Blackboard Learn Mobile App, South Africa.*

1. Introduction

"You can't teach people everything they need to know. The best you can do is position them where they can find what they need to know when they need to know it" [1]. Mathematician Seymour Papert understood that a key factor in education is the accessibility of content. Rapid growth of mobile technologies have triggered a widespread trend among Higher Education Institutions (HEI) to incorporate these technologies into their educational offerings [2], thus placing learners in a position to engage with learning material anytime and anywhere, through the use of mobile devices [3]. HEI are using a wide array of mobile educational offerings in order to engage learners in ubiquitous learning environments [4]. In order to ensure that mobile educational offerings are being utilized at optimum levels, HEI need to constantly analyse the usability and usage of this technology [5].

An example of one mobile educational offering that is employed by HEI is the Blackboard Learn Mobile App (BLMA). It was introduced by Blackboard Inc. in 2010 [6]. The original mobile app that was introduced into the market received negative ratings from users [7][8], and Blackboard Inc. consequently announced, on 16 October 2013, that they had completely redesigned their mobile learning app [9]. The Central University of Technology (CUT), located in the Free State Province of South Africa, is currently using Blackboard (BB) as its Learning Management System and have introduced the BLMA in 2014. The BLMA is currently underutilized at CUT with only 532 users (on the 7th of March 2015) out of approximately 13 000 registered students, a mere 4% of the total number of students. The BB LMS is currently the market leader in South Africa with 52% of HEI in South Africa using it, with Sakai in second place (26% of HEI) and Moodle in third place (21% of HEI) [10]. Several research studies have been conducted on the desktop version of the BB LMS [11][12][13][14]. However, there is currently very little scientific research available that can shed light on the use of the BLMA within the African context. This paper aims to fill this gap.

The aim of this study is to firstly investigate why the BLMA is currently not widely used by students at CUT. Secondly, it aims to present results of a usability study carried out on the BLMA in order to understand the usability issues experienced by CUT students. The paper is structured to firstly give an overview of smartphone penetration, mobile learning, Learner Management Systems (LMS) and the BLMA. The research methodology then follows with the results presented in a number of tables. The paper concludes with the implications of the study.

2. Background

Numerous studies have investigated the desktop version of the BB Learning Management System in various contexts [11][12][13][14]. However, there is currently very little scientific research available that can shed light on the use of mobile technologies pertaining to LMS in an African context. Due to the lack of literature linked to the use of mobile technologies in an African educational context, this review will focus on four areas that support the successful application of mobile technologies in HEI. These areas are: 1) the accessibility of LMS in South Africa; 2) the penetration of smartphones amongst South African students; 3) the types of mobile learning; and 4) the current state of the BLMA. Although the literature presents some of these areas outside an educational or mobile context, the primary focus is their influence on the use of mobile technology in African education.

As the first area of focus, LMS assists instructors with the identification and assessment of learning goals and provides mechanisms to trace the progress towards meeting those goals. It supports the collection and presentation of data that enables the supervision of the learning process as a whole [15][13]. Despite the various advantages that LMS have for students [10], various barriers still exist that prevent South African students from accessing LMS at home. These barriers including limited Internet access at home and high data costs of mobile devices [10][16]. According to the “General Household Survey report” that was published by Statistics South Africa in June 2014, only 10% of South African households reported to have Internet access at home. A total of 30.8% of South African households use mobile devices to access the Internet, with 17.9% of these living in rural households [17].

Secondly, while the use of mobile devices in Africa is ever increasing, the overall smartphone penetration in Africa is estimated to only be between 6% and 15% [18]. However, research conducted by World Wide Worx in 2014 indicates that the smartphone penetration in South Africa among students is much higher, with 84% of students reporting ownership of such phones (Android 38%; Blackberry 32%; Windows 7%; iPhone 7%). Only 10% of South African students reported that they are still using a feature phone [19]. Students indicated that they use their smartphones not only for communication, but also to assist them with their studies. According to 89% of students, smartphones and social media helped them with research related activities while 67% stated that their smartphones helped them to increase their knowledge of their educational modules. Smartphones are also used by 60% of students to share information and 38% reported that their smartphone gives them a channel for discussions with lecturers [19]. It can therefore be argued that many of the South African students have the need and necessary resources to engage in mobile learning.

The third area is mobile learning which may be defined as “any type of learning that takes place in learning environments and spaces that take account of the mobility of technology, mobility of learners and mobility of learning” [4]. The major advantage of mobile learning is that learners can engage with learning material anytime and anywhere. Research in higher education classifies mobile learning into two categories. The first category is the mobile interaction with the LMS, including features such as content downloading,

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course management, communication, discussion forums, and file storing. The second category is related to the use of mobile devices to interact with educational apps, multimedia and simulations [17]. The focus of this paper is on the first category of mobile learning, with specific emphasis on the BLMA and its usage patterns and user experience among Information Technology students at CUT.

Finally, the BLMA was introduced by Blackboard Inc. in 2010 [6]. Reviews of the original app exposed several problems including the inability of the app to handle assessments, assignments and content uploading [7]. Evidence revealed that the app could mainly be used for viewing content and for engaging in discussion forums [6]. In a study at New England University, where both instructor and student perspectives were evaluated in terms of using the BLMA, both research populations indicated that significant improvements with regard to functionality, aesthetics and utility would be necessary to enhance the BLMA [20]. Research conducted by Bond University in 2012 on the perceptions of students using the BLMA on their iPads indicated that the majority of students were neutral when asked if they prefer the BLMA over PC access to Blackboard [21]. Blackboard Inc. subsequently announced at the end of 2013 that they had completely redesigned their mobile learning app after extensive analysis of how students use mobile devices for education. They claim that their updated version of the BLMA simplifies content consumption which will lead to a more engaging user experience and greater productivity [9]. Currently, no published research findings are available to confirm these claims by BB regarding their newly designed mobile learning app. The BLMA is currently underutilized at CUT with only 4% of 13 000 registered students using this app [22].

Based on the aforementioned discussion, it is evident that South African students want to engage in mobile learning, with the aim to access course material related to their studies. This course material is often loaded onto LMS, but accessibility remains a problem, with an increasing number of students turning to mobile Internet access to fulfil their needs. This raises the question as to why the usage of the BLMA, adopted by CUT, still remains extremely low among students, when the mobile solution should be the preferred method, especially after updates by BB to improve the user experience. It is therefore the aim of this paper to determine: 1) Why CUT students are not using the BLMA? 2) What CUT students user experiences are of using the BLMA?

3. Methodology

A cross-sectional design was used where both quantitative and qualitative data was collected using survey questionnaires as the data collection instrument. Cross-sectional designs are used when a cross section of a population is sampled and studied at a single point in time using one questionnaire, one survey, or one observation [23]. The reason for using a cross-sectional design was due to the fact that it is a relatively inexpensive method enabling the researcher to gather similar data from a large number of respondents from a cross section of the Information Technology (IT) department at CUT. The target population of this study is therefore restricted to freshman to senior students within this department who enrolled for different modules during the first semester of 2015. The study employed purposive sampling as the researchers only used students that were enrolled in BB modules where the researchers had instructor's rights. Instructor's rights enable the researchers to directly post surveys on the BB page of each module and retrieve completed surveys from BB. This resulted in students from six different modules (first-year to final-year modules giving rise to a cross section of the study) completing the relevant survey questionnaires. Announcements were posted on BB to urge students to complete the two survey questionnaires which were designed for this study.

Due to the limited availability of prior studies on the BLMA usage, the questions in the surveys were based on a semi-structured interview that was initially conducted in January 2015 amongst IT students at CUT. The first survey questionnaire thus developed was only distributed to first-, second- and third-year students and focused on gathering basic data on why and how students used their mobile devices to access the BB LMS. No usability questions were asked in the first survey questionnaire. The reason for only using these students (mainly freshman students) to respond to the first survey questionnaire is due to the fact that the majority of these students would have had less than two years interaction with BB, and would therefore not really be able to evaluate the usage of the BLMA over an extended period of time. The number of respondents to the first survey questionnaire was 319 (n_1 = 319) which included mainly closed-ended questions giving rise to quantitative data.

The second survey questionnaire was only distributed to fourth-year students. The reason for only using senior students was due to the fact that they would have had more than two year's interaction with BB, and would be in a better position to evaluate the usability of the BLMA. A large percentage of these fourth-year students are furthermore employed during the day, affording them a little more financial freedom to cover the data costs associated with the use of the BLMA and also in acquiring mobile devices that can support this app. In order to be able to respond to the questions in the second survey, students had to complete activities by making use of the BLMA that was installed on their mobile devices. The questions that the students had to respond to were based on the most widely used features of BB at CUT which were identified by one of the senior BB instructional designers at CUT. Closed-ended questions (5 point Likert-scale) and open-ended questions were included in the second survey questionnaire, giving rise to both quantitative and qualitative data. A total of 57 students completed this second survey questionnaire (n_2 = 57).

4. Results

The first objective of the study was to determine why students are not using the BLMA. Table 1 provides a profile of the respondents in terms of their biographical data. This was gathered for the first- to third-years students (n_1 = 319) using the first survey questionnaire. Table 1 reveals that there are almost twice as many male IT students (66%) than female IT students (34%). This gender disparity is similar to that found in the United States where more than twice as many men graduate from computer science programmes than woman do [24].

Table 1. Biographical information

Age	n	%
18-20	117	37%
20-22	137	43%
22-24	51	16%
24+	14	4%
Total	319	100%

Gender	n	%
Male	212	66%
Female	107	34%
Total	319	100%

Table 2 presents data showing the type of mobile device students own as well as the number of years that they are using BB. It can be seen that 17% of students reported owning a feature phone, with the remaining 83% of students owning a smartphone. This is in line with the 84% of tertiary students in South Africa which owns smartphones as established by research conducted by World Wide Worx [19]. The BLMA only caters for Android, iOs and Blackberry devices and is not supported on Windows smartphones. The percentage of students owning Windows phones is 8% from the total, which lowers the overall percentage of students which can access the BLMA from their smartphones to 75%.

Table 2. Type of mobile device and Blackboard experience

Type of mobile device	n	%
Android	142	45%
Blackberry	81	26%
Feature phone	53	17%
Windows	25	8%
iOs	16	5%
Total	317	100%

Years using BB	n	%
0-1	145	45%
1-2	64	20%
2-3	53	17%
3+	57	18%
Total	319	100%

Table 3 displays a comparison between the different ways of accessing BB on a smartphone to the number of years of using BB. This table reveals that 50% of 145 students who reported less than one year of BB interaction reported never accessing BB with their mobile device. However, 46% of 57 students who reported more than three years of interaction with BB also indicated that they never accessed BB with their

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mobile device. The students with the greatest amount of experience in using BB furthermore reported the lowest percentage of using the BLMA (9%). These results tend to imply that the usage of the BLMA is not dependant on the years of experience with BB, suggesting that the years of BB interaction may be excluded from being a factor leading to the underutilisation of the BLMA. The total percentage of freshman IT students that access BB with the BLMA is 13%, which is more than three times higher than the overall access rate of CUT students (4%) [22].

Table 3. Mobile access of Blackboard and experience in years

	Years using BB								
	0-1		1-2		2-3		3+		Mean
How do you gain access to BB on your mobile device?	n	%	n	%	n	%	n	%	%
I never use my mobile device to access BB	73	50%	23	36%	21	40%	26	46%	43%
By using the web browser of my mobile device	56	39%	30	47%	24	45%	26	46%	44%
By using the BLMA	16	11%	11	17%	8	15%	5	9%	13%
Total from Table 2 with regard to BB experience	145		64		53		57		

Table 4 indicates that students frequently access BB by using a PC or laptop, with 72% of respondents accessing it more than three times a week. In contrast, only 17% accessed it more than three times per week by using a mobile device with 50% of students reporting that they never access BB via their mobile devices. This corresponds to the results given in Table 3, where 50% of the 145 students with less than one year experience with BB indicated that they never use their mobile devices to access BB.

Table 4. Frequency of accessing Blackboard

	By using a PC or laptop		By using a mobile device	
	n	%	n	%
Never	8	3%	159	50%
1 time per week	10	3%	43	14%
2 times per week	22	7%	36	11%
3 times per week	48	15%	26	8%
More than 3 times per week	228	72%	54	17%
Total	316	100%	318	100%

Reasons for not using the BLMA provided by students are summarised in Table 5, with their respective rankings. The most important reason cited by students for not using the app is the high data costs associated with their mobile devices (29%). These findings correlate with research conducted by Bere in 2012 where students reported that high data costs are a major disadvantage to accessing BB with their mobile devices [16]. This is followed in 2nd place by students reporting that their mobile devices do not support the BLMA (28%) which is correlated to the fact that 17% of students reported owning a feature phone and 8% reported owning a Windows phone (see Table 2). Neither feature phones nor Windows smartphones can access the BLMA. In 3rd place, students indicated that they have no need to use the BLMA as they make use of the PC's on campus (19%).

Table 5. Reasons why students are not using the BLMA

Reasons why students are not using the BLMA on their mobile device:			
	n	%	Rank
The data costs are too expensive to access BLMA on my mobile device.	78	29%	1
My cell phone does not support the BLMA.	75	28%	2
I do not see the need to use the app, I make use of the PC's on campus.	51	19%	3
I don't know about the app.	35	13%	4
I did try out the app but was not satisfied with the way it worked.	20	8%	5
Problems with internet access of mobile phones.	4	2%	6
Do not have a cell phone.	3	1%	7
Total	266	100%	

These findings, listed in Table 5, are somewhat contrary to findings by the Bond University in 2012, where the majority of students were neutral when asked if they prefer the BLMA over PC access to BB [21]. It is noteworthy that in 4th place, 13% of students reported that they were not aware of the existence of the app. This suggests that the BLMA is not effectively marketed by the E-Learning division at CUT. In 5th place, 8% of students reported dissatisfaction after using the BLMA, and consequently did not continue using it. This implies, to a certain degree, that usability concerns do exist as identified by previous reviews of the BLMA [7][8].

The second objective of the study was to determine how students experience the various aspects of the BLMA. Survey questionnaire 2 was used for this purpose and students responded on how easy it was for them to accomplish several activities by using the BLMA. A Likert-Scale varying from 1 (Strongly Disagree) to 5 (Strongly Agree) was used to obtain responses from students. A summary of the results are provided in Table 6.

Table 6. Experience by senior students of various aspects of the BLMA

By using the BMLA it was easy for me to:	1 Strongly Disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly Agree	Mean	Rank
Access the announcements of my courses.	2%	7%	9%	47%	35%	4.05	1
Access the PowerPoint slides of my courses.	4%	19%	19%	43%	17%	3.63	2
Access the information regarding my upcoming assignments.	7%	11%	18%	47%	18%	3.58	3
Access the general content of my courses.	13%	18%	11%	41%	18%	3.38	4
Complete a test.	9%	16%	27%	41%	7%	3.20	5
Post my comments on the discussion forum and to read other student's comments.	13%	20%	38%	25%	4%	2.87	6
Watch a YouTube Video.	25%	21%	25%	25%	5%	2.65	7

Table 6 indicates that students had the least difficulty with accessing their announcements (mean = 4.05), PowerPoint slides (mean = 3.63), instructions for their upcoming assignments (mean = 3.58) and the general content of their courses (mean = 3.38). Senior students experienced the most difficulties when attempting to watch YouTube videos (mean = 2.65), interact with forums (mean = 2.87) and in completing online tests (mean = 3.20). In addition to the Likert-Scale responses, students were also asked to describe their experiences while engaging in the different activities listed in Table 6. A large number of students who experienced problems with various aspects of the BLMA commented on its slow response time and on the small screen size of their mobile device which does not allow for effective viewing of course content. They also commented that the downloading of course content consumes large amounts of data, while other students were not able to download any files using the BLMA.

While students could easily access the instructions for their upcoming assignments with the BLMA, Table 7 presents data indicating that only 37% of students could submit an assignment via this app.

Table 7. Submitting of assignments with the BLMA.

It was possible for me to submit my assignment via the BLMA.		
False	n=36	63%
True	n=21	37%

The inability of a large percentage of students to submit assignments via the BLMA is a serious usability concern due to the fact that BB is widely used at CUT for the submission of assignments.

5. Conclusions

The aim of this study was to firstly investigate why the BLMA is currently not widely used by students at CUT. Secondly, it aimed to present results of a usability study carried out on the BLMA in order to

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understand the usability issues experienced by CUT students. This was done to investigate the low adoption or usage rate of the BLMA in an African context. The results, based on the data collected from the first questionnaire survey, strongly suggest that two huge barriers to the adoption and usage of the BLMA exist, namely high data costs and unsupported mobile devices. This is in line with findings reported by a previous study that investigated the usage of LMS in a distance learning environment [10], as well as a study that investigated student experiences of ubiquitous learning via mobile devices [16]. The fact that the majority of students access BB via campus computers is probably a direct result of the high data costs. However, it must be noted that CUT has a number of excellent and very accessible computer facilities which could be an indicator that students have a limited need for mobile access.

Information gathered regarding BLMA's user experience is consistent with previous research into the BLMA, which reveals that students are experiencing a number of usability problems [6][7]. This study's findings confirm that students are still experiencing problems with the newly designed BLMA in terms of uploading content, watching YouTube videos, posting replies on discussion forums, completing online assessments and submitting online assignments. Some of the greatest advantages mentioned by students for using the BLMA is the push notifications that is sent directly to their mobile device which keep them up to date with everything that is happening in their courses.

The results of this study tends to suggest that the low adoption rate of the BLMA is related to the high cost of data, the poor usability of the app and the app's inability to function across a range of mobile devices. The first factor can only be addressed through possible partnerships between HEI and mobile service providers in order to lower the barrier for the success of mobile learning. However, the onus must reside with BB to ensure that their mobile product is of the standard required to address usability and access of their product across a wide range of mobile devices.

Some limitations might be related to the collection of data and the interpretation of the results. As a first limitation, some important variables might have been omitted. For example, the respondents' mobile technology literacy was not taken into account, which might have been a huge factor in the successful completion of tasks required for survey questionnaire 2. Secondly, the respondents are all students from the IT department, which could have skewed results due to the fact that they are more knowledgeable with regards to mobile technologies and, in most cases, more open-minded towards emerging technology solutions.

The results of this study could be strengthened by increasing the population size to include students from other faculties in order to better reflect the students' attitude and usage of the BLMA. It is also suggested that the user experience evaluation be expanded in order to better identify and understand the responses from a more diversified student profile. It would probably be best to conduct a usability study with the aid of an evaluation tool, such as the System Usability Scale, in order to determine whether the BLMA simply suffers from a user interface barrier that is complicated to navigate or whether key functionalities have been omitted. However, what is important to note is that academics need to position students in a way that they can find what they need to know when they need to know it, making this ever-more possible through the on-going rapid growth of mobile educational technologies within the African context.

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Creating a Collection of Assets in Electrical Engineering – a Project under Way

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Abstract

Information and Communication Technology tools provide both infrastructure and contents to enhance education. Engineering Education can benefit from ICT tools due to its nature – simulators, animations, online exercises can motivate and help the understanding of dynamic phenomena, for example. Development of good quality courseware is time consuming and requires financial resources. A team of different professional profiles is necessary to introduce good visual quality, develop interactions, etc. In order to lower costs and development time, it is important that contents be reused; this is one of the targets of content developers. A characteristic that contributes to the reuse of contents is their sizes or granularity. Another is the way they are managed to allow them to be searched, found and retrieved. When this happens, they are said to be structured. Besides the contents that are used to build lessons, modules, courses and curricula, there is a smaller digital component that belongs to contents – the asset. Though assets are not used directly in the learning process, they contribute through learning objects. Assets can be structured to be reused too. This work presents a project that created a collection of assets in Electrical Engineering – they are managed by a system that is at the same time an Institutional Repository and a Learning Management System.

Keywords: *asset, courseware, electrical engineering, ICT supported learning, institutional repository, learning management system.*

1. Introduction

This work addresses the convergence of different paths related to the use of ICT – Information and Communication Technology tools in various activities related to higher education in a Brazilian institution. The institution is the Pontifícia Universidade Católica do Rio de Janeiro (PUC-Rio) that has been involved with Engineering Education for almost two decades. The paths can be "walked" separately but, no doubt, yield better results when they converge. In order to understand each path, some background must be presented.

- Institutional Repository

In 2003, Lynch [1] introduced an expression that has been used worldwide since then – Institutional Repository (IR). He defined an IR as: **"A university-based institutional repository is a set of services that a university offers to the members of its community for the management and dissemination of digital materials created by the institution and its community members. It is most essentially an organizational commitment to the stewardship of these digital materials, including long-term preservation where appropriate, as well as organization and access or distribution."** The definition is very broad since it aims at "digital materials created by the institution and its community members". One can think of ETD – Electronic Theses and Dissertations, journals, technical reports, articles, books and courseware. An IR can host, describe, give access and preserve digital resources that are inputs and/or outputs of the educational process. Courseware is of paramount importance as an input; it can also be an output since students can be active developers. This will be mentioned later in this work.

- Learning Management System

Wright et al. [2] defined a Learning Management System (LMS) as: **"An LMS is comprehensive, integrated software that supports the development, delivery, assessment, and administration of courses in traditional face-to-face, blended, or online learning environments."** There are other ways of referring to such systems though this is the most used. It was the choice for this work.

- Learning Objects and Shareable Content Objects

Two expressions are very important in ICT supported learning. They are related to the definition of educational resources. The first is Learning Object (LO) and the second Shareable Content Object (SCO).

LO is defined in page 1 of the IEEE Standard for Learning Object Metadata [3] as: **"For this standard, a learning object is defined as any entity – digital or non-digital – that may be used for learning, education, or training."** LOs are items that can be combined for teaching and learning. Since LOs are not necessarily digital, the definition allows, for example, that laboratory equipment be identified, described and referred along with other educational resources. This is very important in Engineering Education since laboratory activities are a fundamental requirement in educating engineers. In the context of this work, LOs are digital entities.

"The Shareable Content Object Reference Model (SCORM) is a model that references and integrates a set of interrelated technical standards, specifications, and guidelines designed to meet high-level requirements for e-learning content and systems." [4] page 11-4. The SCORM defines SCO as: **"SCOs are the smallest logical unit of information you can deliver to your learners via an LMS."** [4] page 3-3.

Comparing the definitions of LOs and SCOs, it is easy to understand that they have:

- Differences: SCOs are to be delivered via LMSs while LOs can be non-digital, thus not to be exclusively delivered via LMSs. SCOs must be compliant to SCORM specifications that allow them to be delivered by any SCORM compliant LMS.
- Similarities: Both SCOs and LOs have educational purposes and are units/entities.

In 2000, Wiley [5] introduced the terms reusable chuncks of instructional media, reusable instructional components, reusable digital resources, reusable learning objects (LO). In 2009, Alsubaie [6] used the term Reusable Learning Objects (RLO). All these terms/definitions have much in common and, therefore, fuzzy boundaries. The subject of reusing and sharing educational resources has also been addressed in [7] and [8]. CMaps were used to help define the sizes of LOs aiming at their reuse in [9] and [10]. But all the definitions and worries focus the level of the resources that are managed by LMSs and that students and instructors recognize as learning topics. They can have different sizes and scopes, but they have learning objectives.

SCORM defines a lower level digital item – Asset. It is: **"Assets are electronic representations of media, texts, images, sounds, HTML pages, assessment objects, and other pieces of data. They do not communicate with the LMS."** [4] page 3-2. Assets can be building blocks of LOs, RLOs and SCOs and can be redeployed, rearranged, repurposed, and reused in many different contents. Though assets do not communicate with LMSs, they can be stored, described, controlled and distributed by IRs. This work presents a model of managing assets in Electrical Engineering on an IR that is integrated with a LMS.

Section 2 addresses the context of the model and section 3 presents the solution that is under implementation and some partial results. Section 4 discusses the results and points to the next steps.

2. The Context

The context of the project presented in this work is analyzed in two different aspects. The first is the technological platform and the second the digital contents on Electrical Engineering it hosts.

2.1. Technological Solution – the Maxwell System

The technological solution used for this project is the Maxwell System (http://www.maxwell.vrac.puc-rio.br/). It is a large and complex system that combines an IR, a LMS, a subsystem to manage administrative documents and a library of external links of interesting sites. Though the system is currently under the Vice-Presidency for Academic Affairs, it was initially created at the Electrical Engineering Department.

The first version of the system was deployed in the mid 1990s and it was a digital library of courseware in Electrical Engineering. Courseware at that time was very simple since IT tools were more limited. In 1999, PUC-Rio registered the system in the Brazilian Patent Office. As time went by, other types of functions were added as well as other types of contents started being published. Currently the main features of the system are:

- LMS Features

The system offers two "rooms": a Classroom for courses that use ICT tools to support and enhance traditional face-to-face classes and a Virtual Room for distance or blended learning courses. The Electrical Engineering faculty started three undergraduate blended learning courses in 2014, one in the first semestrer of 2015 and will offer one or two more in the second semester of 2015. There are functions to track the students usage of contents. The usual communication tools are avaliable – discussion forum, chat, bulletin board, etc. In the administrative side, there is an agenda, a course schedule, records of grades, a calendar of events and others.

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There are administrative tools for instructors and for system administrators. The system is compliant with the univeristy administrative systems.

- IR Features

All contents that are stored and made available through the Maxwell System are described according to national and international standards or best practices. The system is compliant with three metadata standards: DCMES – Dublin Core Metadata Element Set (ISO 15836) (http://www.dublincore.org/) , ETD-ms – an Interoperability Metadta Standard for Electronic Theses and Dissertations (http://www.ndltd.org/standards/metadata) and MTD2-BR – Padrão Brasileiro de Metadados para Teses e Dissertações (http://oai.ibict.br/mtd2-br/MTD2_Fev2005.doc). The last two are specific for online theses and dissertations (ETD); one is international and the other is Brazilian. The description of courseware has many elements of the LOM Standard [3].

Concerning interoperability with other repositories and union catalogs, the system is an OAI-PMH – Open Archives Initiative Protocol for Metadata Harvesting (http://www.openarchives.org/) data provider. It provides metadata of all contents in the DCMES set and of ETDs in both DCMES and MTD2-BR sets.

The current collection has over 19,000 titles. The largest subcollections are:

- ETDs – over 7,300 (ETDs have been mandatory since August 2002)
- Senior Projects – over 3,600
- Courseware of different natures (texts, videos, interactive modules, simulators, etc) – over 2,500
- Articles and other journal contents – over 1,500

Courseware is mostly concentrated in Electrical Engineering topics. For this reason, the system offers an interface that is an aggregator of all EE contents it hosts. It is called *Elétrica On-line* (http://www.maxwell.vrac.puc-rio.br/eletricaonline/) and through it the user can access ETDs, senior projects, courseware, articles and external links of EE contents that are in Open Access.

Two undergraduate and one graduate courses are using videos to substitute for traditional face-to-face lectures. Currently there are 34 videos of the Electric and Electronic Circuits course (one more is under development) and 22 (approximately 25 more to come) of the the Substations and the Distribution of Electrical Energy courses. In the second semester, one more course in the area of Power Systems will use videos. These videos are not assets because they are managed by the LMS.

2.2. Courseware in Electrical Engineering

As mentioned in the previous subsection, most courseware is in Electrical Engineering. In order to set a designation for the courseware, the term LO will be used. It was chosen because the courseware is not SCORM compliant. All LOs are "seen" and delivered by the LMS. Over and above, each LO is described on the IR; LOs can be searched and retrieved by the regular IR functions.

This is an interesting characteristic of this model – integration of an IR and an LMS – it allows courseware to be available to users even when they are not students in a class. The system has five access levels and the author decides which one each LO will have. The choice of access level is used to all contents on the Maxwell System, not only to LOs. Even if LOs are restricted to some users, they can be searched and found, and their metadata can be examined. Access statistics are applied to LOs as well as to other titles of the collection.

Development of courseware is expensive and time-consuming. It involves different profiles of professional staff – content developers, web designers, programmers, experts in interactive modules, animation programmers, etc. for this reason, reuse is so important. All the actions related to reuse of courseware on the Maxwell System [7] - [10] focused on LOs. Examination of the contents of LOs indicated that some "parts" were common to many; one example is the schematic representation of the RLC series circuit and a second example is an input-output block diagram representation. These parts were native of the LOs and were created with them. This led to useless work that could have been avoided. The solution of this problem is addressed in section 3.

2.3. Description of the Courseware on the Institutional Repository

The DCMES and all other metadata sets have an element called "type" whose objective is to describe the nature of the resource. The vocabulary for this element can be found in section 7 – DCMI Type Vocabulary of DCMI Terms (http://dublincore.org/documents/2012/06/14/dcmi-terms/?v=elements#type). The vocabulary has the following set of terms: (1) Collection; (2) Dataset; (3) Event; (4) Image; (5) Interactive resource; (6) Moving image; (7) Physical object; (8) Service; (9) Software; (10) Sound; (11) Still image; and (12) Text. Each term may identify many different types of contents. One example is text that can be a thesis or an assignment or an article or a book or etc, a second example is moving image that can be a video or an animation. For this reason, the Maxwell team added subtypes to each type. Subtypes have the purpose of making the description more specific. A third classification of a content is associated with its conceptual nature – two examples are scholarly publications and technical documents.

Thus the description of all contents on the system is very detailed and precise. But this description did not apply to the "parts" that were native of the resources and therefore embedded in them. These parts are identified as "assets" in the SCORM classification. It is important to remember that they are not managed by the LMS; but they can be managed by the IR. This is a very interesting and important feature of the system – integration of two management systems.

In order to bring efficiency to content development, the concept of asset was added to the system. The description of an asset follows the same practice of any other digital resource, except that a Bollean Variable is associated to the description to indicate that the digital content is an asset (or not). Section 3 describes how assets are being added to the system.

3. Assets

Once the problem was identified – how to reuse assets in the creation and implementation/development of LOs, it was necessary to solve it. The solution was divided in three parts:

- Part one was to consider assets as digital contents that are marked as such on the database of the IR – an enhancement of the data model was necessary. The decision was to use a Boolen Variable to tell if a resource is an asset. Besides this asset identification of the digital file, all description is like that of any other resource. This part addressed the modeling of assets on the system database and it is finished.
- Part two is to find assets in LOs and extract them to be described and saved. Since the number of LOs in large, the decision was to start with the ones that last longer; this means the ones the are not discarded at the end of each school term. When they are described, they receive a number on the IR – it is sequential and is in the same counting of all other resources. At this stage, the LOs that contain the assets are recorded so that part three can be implemented. Part two is under way due to the large number of LOs available on the system.
- Part three is to describe the relations of each asset with the LOs. To understand part three, it is necessary to consider the DCMES element which allows the specification of relations among contents. In section 2 – Properties in the / terms / name space of the DCMI Terms (http://dublincore.org/documents/2012/06/14/dcmi-terms/?v=elements#type), some possible relations are presented. This does not mean that new relations cannot be introduced, since the standard is open for local adaptations. In the standard, there is a set of relations "hasPart" and "isPartOf". This set was used to describe relation among assets and LOs. This is not explict on the database, since this relation is contained in a table. Part three is under way since it goes along with part two.

A comment is necessary at this point – all LOs and assets created after the project started are following the identification and relation description practices. So, no new "problems" are being introduced. It is quite interesting that this new view of the management of digital resources has allowed the reuse of assets in the "old" LOs for contents under development.

The following subsections present partial results of parts two and three. The results come from the examination of 51 LOs of different types, objectives, formats and conceptual natures; two are still under development or editing. They were:

- Class notes – 9 volumes (3 titles)
- Sets of proposed exercises – 3
- Tutorials – 2
- Learning modules – 35
- Course guides of blended learning courses – 2

The first three are texts and the other two are hypermedia documents. They were created by eight different authors. One of the Class Notes requires a lot of editing since the author is new in the ICT – Information and Commuication Technology supported learning. It will probably be divided in two different resources – Class Notes and a Set of Proposed Exercises; at the moment it is still one document.

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The number of assets is 602. This means the average number of assets in this set of LOs is almost 11.8 per LO. The following subsections address the redundancies, reuse, etc that are a consequence of this analysis. The work is under way.

3.1. Types and Subtypes of Assets

This is a work under way, so the results are partial and will change. The types and subtypes of assets that were identified in the 51 LOs were:

- Interactive resource – simulator
- Moving image – animation
- Moving image – video
- Software – routine
- Still image – block diagram
- Still image – graphic
- Still image – photo
- Still image – schematic representation of circuits and/or motors
- Still image – screenshot
- Still image – simulation diagram

It is important to remark that the videos that were mentioned in 2.1 are quite different from the ones that are assets. They are longer since they present a full lecture and are managed by the LMS. The videos in the previous list are assets because they are short, address a specific topic and are embedded in a content (a learning module or a course guide); the LMS does not "see" them.

3.2. Digital Formats of Assets

The assets were found in a variety of formats.

- Interactive resource – simulator: html (html5)
- Moving image – animation: html (html5)
- Moving image – video: flv and mp4
- Software – routines: m (MATLAB® format)
- Still images – docx, gif, jpg and png

The formats used for still images deserve a special comments.

- Most textual documents were written using MS Word® and then converted to pdf/A. For this reason, many graphics and block diagrams were objects in the files that had been drawn and could be edited using the Drawing Tools. In order to make them reusable, the original object was saved in a separate file in docx format and a png file was generated to be used in other LOs. The original docx files were maintained due to the ease of editing. In this case, the metadata description informs the existence of two digital format files of the same resource; this is usual in digital collections management. An example of such situation is the block diagram representation of an input-output relation of a linear time-invariant monovariable system – it existed in 10 different LOs; the png asset substituted for them.
- Many graphics, block diagrams and schematic representations of circuits were drawn using PRESTO [11], a tool that was developed by two undergraduate students that were members of the Maxwell System team. The corresponding images were saved either in the png or jpg formats.
- Many still images were difficult to draw and a designer had created them under the supervision of the author(s). These are either in png, jpg or gif formats. Many have more than one format; the metadata description contains such information as in the previous case.
- Many textual documents had images that were hand drawn and scanned. These are undergoing one of the three previous processes.

Some examples of assets follow.

Example 1: Two simulators. One (figure 1) is of an RLC series circuit and the other (figure 2) of a Mass-Spring-Damper system – they are interactive resources, each one is used (embedded) in two different learning modules and they are programmed in html5. It is importante to remark that they use the same code – only the screens are different. This means the code is used in four learning modules.

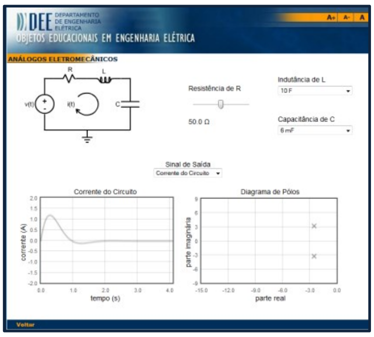

Figure 1 – RLC Circuit Simulator.

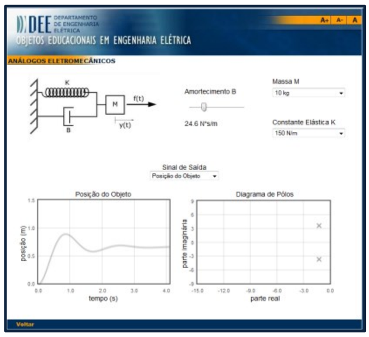

Figure 2 – Mass-Spring-Damper System Simulator.

Example 2: Two videos. One (figure 3) about eigenvalues and eigenfunctions and the other (figure 4) about LDR – they are moving image (+audio), each one is used in one module and their format is mp4.

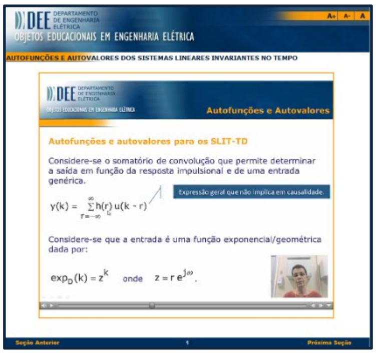

Figure 3 – Eigenvalue and Eigenfunction Video.

Figure 4 – LDR Video.

Examples 1 and 2 show quite elaborate assets. The next example shows simple assets.

Example 3: Four images. One (figure 5) is the schematic rerpresentation of an RLC circuit; used 21 times. The second (figure 6) is a drawing of a thermoelectricity phenomenum; used twice. The third (figure 7) is a graphic; used 10 times. The last (figure 8) is a screenshot of an audio signal analysis; used twice. They are still images and some are pgn and others gif.

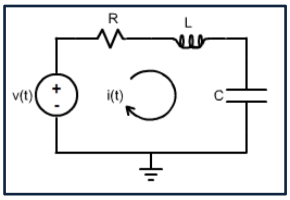

Figure 5 – RLC Circuit Schematic Representation.

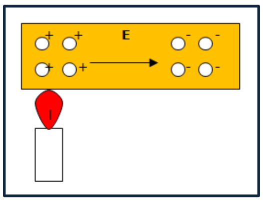

Figure 6 – Thermoelectricity Phenomenum Drawing.

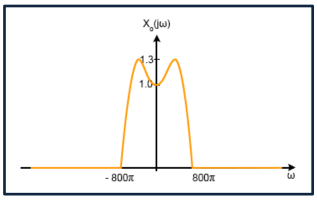

Figure 7 – Graphic.

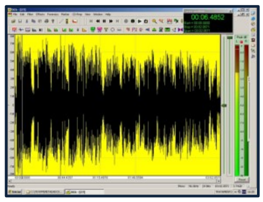

Figure 8 – Screenshot Audio Signal Analysis.

At the moment, a group of undergraduate students is working to develop exercises using SciLab (http://www.scilab.org/). They are working with topics in Controls and Servomechanisms. The exercises will be added to the Maxwell System either as assets in the course guide (of the blended learning courses) or in the learning modules. So, software assets with a sci extension will be added to the IR.

A comment is important concerning the participation of students in the creation and development of courseware – undegraduate students have been very active members of the development team. They create, implement and test courseware of various natures.

3.3. Metadata Description of the Assets

The assets are described using the metadata set that the system supports. The access levels and the possibility of sharing the resource are used too. The relation information is not new to the system either. The only additional information is that the resource is an asset. This has two objectives. The first is for the set of search programs

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that are used by the general public not to search the assets collection. The second is for searches for assets to find the files – this will help content developers (reuse what they need). When a docx file is available, the author may modify the content and create a new asset, as long as the original author grants this permission.

3.4. Current Numbers of the Assets

As mentioned before, this is a project under way and it has a huge backlog. This backlog is due to the many years of courseware development with no concern on reuse of assets. All focus on reuse was on LOs [7] – [10]. Currently, there are two actions that run in parallel.

- The first action refers to new LOs developed after this project started. All assets are identified and managed by the system. This will be a permanent action.
- The second action addresses the problem of all assets that exist in LOs tha have been developed over the many years. The creation of an assets collection in Electrical Engineering requires the following steps to include the "old" assets:
  - Examine all LOs to find assets in each one.
  - Extract the assets from the LOs – in some cases the procedure follows the specification presented in subsection 3.2 concerning LOs whose priginal format was MS Word®.
  - Create the digital files that correspond to each format of each asset.
  - Describe each asset on the system and upload the digital files.

Both actions are under way and the results, in terms of numbers, are shown below. Table 1 contains the numbers of identified assets per type. All numbers are changing as the work progresses.

- Assets that have been found (old and new) up to now – 768
- Assets that have been described (using a spread sheet) – 424
- Number of LOs containing the 424 described assets – 51
- Average number of described assets per LO – 8.31
- Number of uses of the described assets – 602
- Average use of a described asset – 1.42
- Assets whose files were extracted and/or generated and that were added to the system – 151

Table 1. Numbers of described assets per type.

Types	Numbers	%
Interactive resource	17	4.0
Moving image	54	12.7
Software	8	1.9
Still image	345	81.4
Total	**424**	**100.0**

There is still much work to do concerning the assets that were found but not identified/described. Besides this work, there are over 250 assets that require extracting and cataloging on the IR. And then, there ar many other LOs to examine. There is no doubt that the numbers will change.

3.5. Managing Assets in the IR

Lloyd [12] defined **"Structured content is that which has been classified, and stored in a way that makes it easy to be found and used. Unstructured content is all other content."** All courseware on the Maxwell System are structured content since they are desscribed using a metadata set with many elements and compliant with international standards and practices. At the same time, assets were not "seen" by the IR side of the system, since they were embedded in other contents. By creating a colletion of assets, they became structured contents that can be found and used. The system is ready to deal with all types of digital contents. It offers many functions to different types of users. They include search functions over the complete set of digital resources that are cataloged on the system. Once assets started being cataloged, the search functions applied to them. At the same time, some functions will be modified to filter the results to retrieve assets only – they will useful to content creators who will want to know what is available. Another enhancement on the search & retrieve functions will to automatically display the asset(s) with the results. The development of new functions is under way.

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4. Comments and Next Steps

The decision to start this project seems to be right. The discovery of such high number of assets in the LOs in Electrical Engineering indicates that more LOs can be developed using them. The fact that they are becoming structured contents means that they can be searched and found. One remark is important – the assets are still assets, i.e., they are not managed by the LMS part of the system. The management of the assets by the IR part of the system made them structured contents.

There is still a lot of work to be done concerning the LOs that were created before the project started. This work will be performed because the results will yield productivity gain in content creation. Authors will benefit. The next steps concerning the system are to develop some statistics on the nature, subject, etc of the assets. One special information is of paramount importance – the current degree of reusability of assets. This can be found by the proper analysis of the relations among resources that are recorded on the database. Information on authors allowing reuse and/or creation of new assets based on the original works will help reusability.

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Developing the C-EWBST of Digital Multimedia Instruction for Vocational High School Curriculum in E-Learning System

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Abstract

In this rapid transmission of information and innovation in the 21st century, through interactive computer multimedia instruction materials, not only as an auxiliary tool when teaching, but also allow students to self-study after school. Most of experts believe that the vocational skills certification system is the assessment, the best way to skill teaching and checklist the vocational training of vocational education, industrial wiring skill learning is a hands and brain skills formation process of circuit theory to understand, but after long-term operation to achieve the learning outcomes. Through lectures of the digital multimedia teaching methods, we can understand the students' reactions and views of multimedia teaching, thereby improve and enhance the skills of teachers in the use of multimedia teaching, improve teaching effectiveness.

Therefore, this subject of study will step the Class C Electrical Wiring Branch Skill Test (C-EWBST) accredited by teaching technical subjects design and planning, research and development made into a suitable computer interactive multimedia materials, the use of Flash and other software designed for students to develop self-learning and digital textbooks. And convert APP software, built on the site, when the mountain peak of action available to play and operate the vehicle to address the skills of students with learning difficulties in industrial wiring and complexity of possible ways, but also provide students with the individual,repetitive and immediate concept of learning and the active construction of knowledge, environment and platform.

Finally, offer a number of findings and recommendations for vocational teachers, vocational training institutions and education authorities.

Keywords: *Industrial wiring [1], Skill test [2], EWBST [3], digital learning [4], multimedia digital design [5]*

1.Introduction

1.1. Research motives

Under rapid transmission of information and innovation in the 21st century, interactive multimedia is not only used as instructional materials, but also self-study tools for students at home. Many experts suggest that the vocational skills certification system is the best approach to exam and asset the skill teaching and vocational training. Among which, the learning of industrial wiring is to develop skills that require both thinking and techniques, as well as the understanding of circuit theory and long-term practice. The digital multimedia teaching method can allow teachers to observe students' reactions and thoughts, thus improving the application of multimedia teaching and enhancing teaching effectiveness.

Considering the importance of practice curriculum and digital teaching at present, this study planned the teaching contents for Class C Electrical Wiring Branch Skill Test (C-EWBST) for vocational high school students, and developed multimedia teaching materials for C-EWBST prep course. Flash was used to develop the multimedia digital teaching materials for self-learning of students. The program was then converted into APP and provided online. The vivid images, clues and sound effect could promote students' learning motivation and interest. The teaching materials give attention to both exercise and feedback functions, in order to enhance the self-study or teaching effect. The teaching material resources were constructed on the teaching website to provide individual, flexible and adaptive environment for self-study. The diversified learning mode could enhance students' confidence and learning achievement.

1.2. Research purposes

Based on the research motives, the C-EWBST practice unit for the second year curriculum of the Department of Electrical Engineering of vocational high school was taken as subject. Flash was used to develop multimedia materials suitable for self-study, evaluation of learning effect, teaching aid of practice curriculum. The teaching materials were provided online for students at anywhere and anytime. The program is expected to create an environment for repetitive learning, active construction of knowledge and skills, and development of teaching materials. The teaching effectiveness can facilitate the integration of information technology into vocational high school education. The effectiveness of e-learning was observed to determine the differences among students' academic performances, computer self-efficacy, and learning satisfaction, and analyze the influences on learning effectiveness.

2.Literature review

2.1. E-learning behavior

The use of internet on learning can be divided into three types, information communication, data retrieval and data transmission (Lin, 2000). The information communication function refers to e-mail, bulletin board and real-time chat system. The second function is data retrieval, which is the most compatible and potential system in the present Internet development. A variety of information can be integrated, including text, sound, images and animation. The third type is data transmission, based on the FTP (File Transfer Protocol), any two computers of different systems can transfer files to each other, providing mutual sharing, information exchange and cooperative learning for users. Chen and Lin (2002) suggested that students' e-learning behaviors include continuous learning type and interrupted learning type and network active type and network passive type.

E-learning behavior uses network as the learning interface. Yao (2001) indicated that e-learning behavior includes the number of logins, hyperlink, self-assessment, personal discussion, notice posting and all scoring. The network is characterized by recording the learning process of learners.

Therefore, when the students engage in e-learning, the e-learning platforms can record online study behaviors. There are many factors influencing students' learning behavior, including personal factors, teachers' instruction, curriculum design, learning activities and learning environment (Wang and Liao, 2008). The factors affecting learning behavior is learning motives, while belief and personal background have partial influence on learning behavior. The dimensions of learning behavior is lesson or learning related learning behavior, which includes the number of logins, number of notices and the times of reading. It is important for the teachers to analyze

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students' learning on network platform according to the learning portfolio to know the students' learning situation (Shih, 2009).

2.2. Multimedia digital design

Multimedia system covers different types of media, such as text, images, graphics, sound, animation and videos. Different computer programs can be used to evolve the traditional computer-aided instruction multimedia (CAI) into interactive multimedia. The main characteristic of design is that different media designs, such as animation, sound and pictures, describe lesson content or comment examples. The system and learners interact with each other, so that learners are more interested in learning, and are more likely to think about and understand the course contents (Bai, 1997).

2.3. E-learning

The system structure of digital learning consists of images, sound, storage media, interface and editing software. It is designed and constructed by instructors. The lively teaching materials can expand the learners' view, and triggering the learning motives through overall interaction. Such interaction is a two-way communication mode. The interactive process is a nonlinear process, helping the students to create and absorb the knowledge concepts to be learned. The interactive digital learning style is lively, and encourages in-depth observation and repetitive learning. As a result, the learning effect is more effective than traditional one-way or passive teaching. It can enhance the learners' willingness to learn. It is obvious that the digital learning has been regarded as an effective way to upgrade the teaching quality and overcome the space-time limitation of learning (Chuang and Liu, 2006), as well as helping the learners to achieve effective learning and feedback.

The characteristics and advantages of digital learning:

a) Available anywhere and anytime, matching the fast pace of the modern society, and overcome the space and time constraints of traditional teaching.
b) Transcending the learning mode of traditional teaching, "digital learning" should not be viewed from the perspective of traditional learning, but should be regarded as a learning mode that overturns traditional education training.
c) The internet technology allows real-time update, use and storage of e-learning material, as well as sharing teaching or information.
d) The information of specific topics can be searched by data retrieval techniques.
e) The process of learning can be recorded completely for individualized learning.

2.4. Skill test

The skill test is a test that evaluates the skill proficiency of technical personnel. A paper-based test is held to determine whether the subject has reached a certain level of technical ability. Those passing the test would be awarded the certificates.

The technique or skill to be tested in the skill test covers cognition, affection and operation skills. The test pays equal attention to learning and skill, as well as reliability and validity. The skill tests are often held by schools with the intention to emphasize the practice of skills and improve educational equipment. Learning the test-related skills is important to the students.

3.Research and design of teaching materials

3.1. Research and development framework

The multimedia interactive teaching materials are designed and developed for vocational high school in response to the reduction of practice curriculum, which may lower the teaching quality and learning efficacy. Integrating information technology into teaching is an inevitable trend of times. Concerning the C-EWBST for the students of Department of Electrical Engineering of vocational high schools, this study developed multimedia teaching materials for the C-EWBST prep course. By facilitating self-study, it is expected to increasing the passing rate of the students in the skill test and applying their learning in practice curriculum.

The structure diagram of the design and development of the multimedia teaching material is shown in Figure 3-1 (Chuang and Tsai, 2009). In order to integrate the teaching material into the teaching site, the design and development process followed the 7 elements below:

3.1.1. Background analysis:

To know the current condition of practice curriculum of Department of Electrical Engineering of vocational high schools, to analyze the present practice curriculum under the impact of new course implementation, the practice-oriented and theory-assisted curriculum design of specialty and practicum, to discuss the characteristic variance analysis of traditional learning and multimedia learning in practice curriculum teaching.

3.1.2. Multimedia accomplishment:

Use Flash and Photoshop to develop multimedia materials, to develop and design multimedia course, and analyze the multimedia material production principle and skills; the interactive multimedia teaching material factor is added to curriculum framework and converted into APP.

3.1.3. Planning and design:

The multimedia material presentation framework and key item menu are developed according to the instructional objective of C-EWBST prep course of Department of Electrical Engineering of vocational high school; the connectivity of various frameworks is checked at any time during development.

3.1.4. Expert consultation:

The expert opinions were consulted during the development process, so that the design of multimedia materials meets the demand of teaching and trigger active learning.

3.1.5. Integration into teaching:

The multimedia materials are integrated into teaching; after the multimedia materials are produced and tested, they are integrated into practice curriculum to assist in teaching, so as to increase the passing rate in the skill test.

3.1.6. Teaching website:

To construct a teaching website and publish the teaching materials on the website; the materials are also converted into APP for students to download, thus facilitating self-study, construction of knowledge system, and repetitive; it is expected to be an effective teaching aid.
https://1eb635493cfe28f662a2627b1c88d480b01abe1e.googledrive.com/host/0B5UAtI6diUROYm5IY0poNl1cHc/
APP: https://play.google.com/store/apps/details?id=air.main5.A2012&hl=zh-TW

3.1.7. Effect feedback:

The students can review their learning effect. Future study can discuss whether the integration into teaching would improve the teaching effect and increase the passing rate in the skill test.

3.2. Applicable subjects

The multimedia materials are applicable to the students of Department of Electrical Engineering of vocational high school for C-EWBST.

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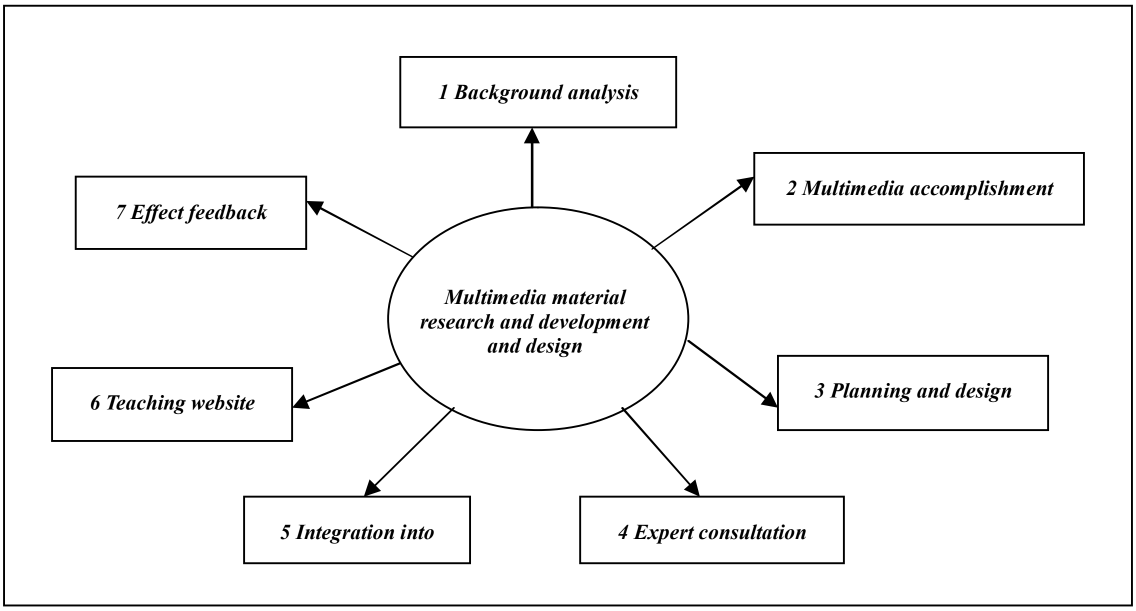

Figure 3-1 Multimedia material research and development and design structure diagram

3.3. Design tools

3.3.1. Self-developed multimedia C-EWBST teaching materials:

Flash and Photoshop are used to design nine digital interactive teaching material skill test items. Each item contains test item circuit operation process and principle, operation of matrix board component, phonetic circuit operation comments.

The phonetic circuit comments can switch the action to matrix board component and the industrial wiring circuit operation process. The circuit operation is displayed by actual elements, helping the learners know the circuit theory.

3.3.2. Questionnaire tools:

After integration into teaching, a questionnaire was designed to explore the learning satisfaction on the multimedia C-EWBST teaching material, in order to further improve the learning effect in the future.

3.4. Scope and limitations

This study only developed multimedia animation teaching materials for C-EWBST prep course of Department of Electrical Engineering of vocational high school.

4.Teaching material structure and meaning

4.1. Website teaching materials:

Product presentation, including photos, drawings, teaching materials and voice, integrated by Flash as follows: (Using Google Chrome browser)

https://1eb635493cfe28f662a2627b1c88d480b01abe1e.googledrive.com/host/0B5UAtI6diUROYm5IY0poNl1cHc/

APP: https://play.google.com/store/apps/details?id=air.main5.A2012&hl=zh-TW

4.2. *Structure and meaning factors*

Multimedia C-EWBST teaching material design structure and meaning factors, the meaning factors include :
1) Single-phase induction motor forward/backward rotation control.
2) Drying cylinder control circuit.
3) Electric air compressor control circuit.
4) Three-phase induction motor Y-Δ reduced-voltage starting control (1).
5) Three-phase induction motor reactor reduced-voltage starting control.
6) Two conveyer belt motors sequential operation control.
7) Two pumps alternative operation control.
8) Three-phase induction motor forward/backward rotation control.
9) Three-phase induction motor Y-Δ reduced-voltage starting control (2).
, compiled in Table 4-1.

Table 4-1 Design structure and factors of C-EWBST teaching materials

Structure	Item	Operation description	Circuit diagram operation switching	Background music
Content factors	1 Single-phase induction motor forward/backward rotation control 2 Drying cylinder control circuit 3 Electric air compressor control circuit 4 Three-phase induction motor Y-Δ reduced-voltage starting control (1) 5 Three-phase induction motor reactor reduced-voltage starting control 6 Two conveyer belt motors sequential operation control 7 Two pumps alternative operation control 8 Three-phase induction motor forward/backward rotation control 9 Three-phase induction motor Y-Δ reduced-voltage starting control (2)	Circuit diagram operation decomposition	Circuit module operation decomposition	Background music switching

4.3. *Teaching material content examples:*

Figures 4-1-1 contents~ 4-1-17 are constructed by APP software, as shown in Figures 4-1-1-4-1-17:

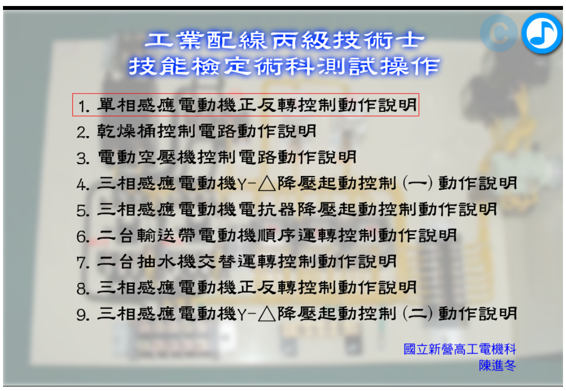

Figure 4-1-1 Contents

Figure 4-1-2Item 1 layout

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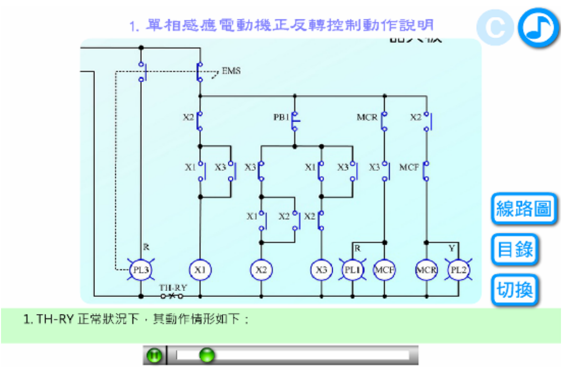

Figure 4-1-3Circuit diagram description

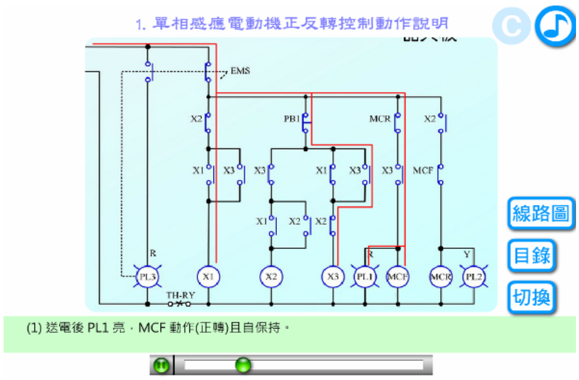

Figure 4-1-4Circuit diagram operation description and voice

Figure 4-1-5Item 1 circuit module operation decomposition

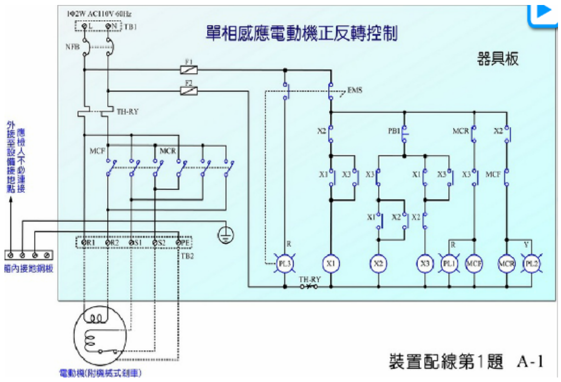

Figure 4-1-6Item 1 circuit diagram

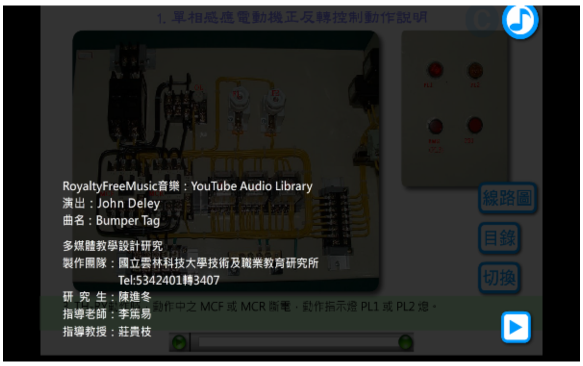

Figure 4-1-7Copyright description

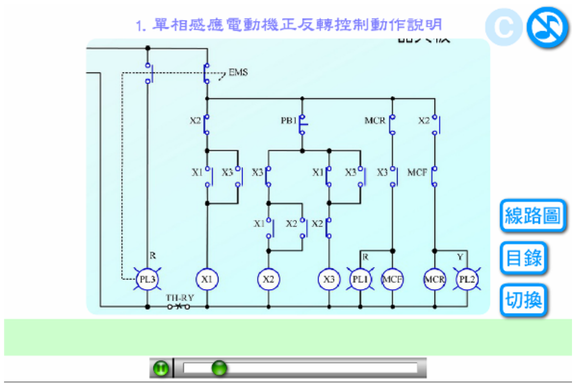

Figure 4-1-8Background music switching

Figure 4-1-9Item 2 layout

Figure 4-1-10Item 3 layout

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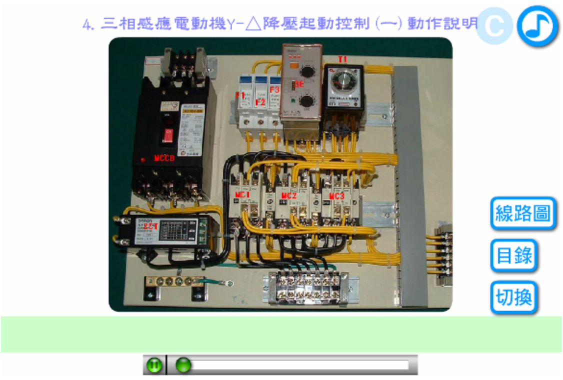

Figure 4-1-11Item 4 layout

Figure 4-1-12Item 5 layout

Figure 4-1-13Item 6 layout

Figure 4-1-14Item 7 layout

Figure 4-1-15Item 8 layout

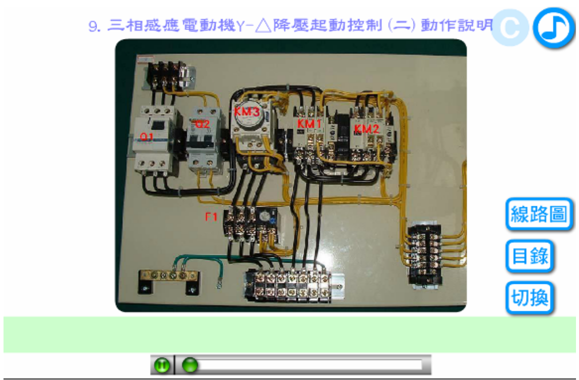

Figure 4-1-16Item 9 layout

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Figure 4-1-17 APP software construction

5.Conclusion and suggestions

5.1. Conclusion

In the 21st century of rapid transmission of information and innovation, teachers should utilize the features of e-learning, use computer multimedia to design teaching materials, and design good interactive learning scenarios and multimedia interactive teaching materials, which can be teaching aids for teachers. Students can thus engage in self-study and improve learning effectiveness.

This study designed and developed multimedia C-EWBST teaching materials. Flash was used to develop the multimedia digital teaching materials for self-learning of students. The program was then converted into APP and provided online. Students could download the APP on their mobile devices, in order to overcome the learning difficulties and complexity in electric wiring. The individual, repetitive and real-time learning concept and a platform for active knowledge construction could bring substantial benefits to the students. Overall, the objectives of the design and development of this teaching material are achieved:

1) The multimedia teaching material can trigger students' active learning, and increase the learning effectiveness in practice curriculum.

2) The interactive software can help students to understand the items of the skill test. The APP can be downloaded by students to mobile carriers to study at any time, making learning more interesting.

3) The multimedia teaching references for teachers are made available online and transcend over the traditional teaching approaching, thus manifesting the information era.

4) A learning website is developed, and multimedia materials are made available, thus providing students with self-study, repetitive learning, and learning efficacy.

5) Flash can present complex procedures into interesting animation, thus enhancing the students' comprehension and reducing teachers' pressure.

5.2. Suggestions

1) Integrating more multimedia teaching in practice curriculums so as to reduce the time spent by teachers on explaining the content and demonstrating the operation; allow vocational teachers to experience the feasibility of integrating multimedia instruction into practice curriculum, so that they could develop teaching materials that match the teaching and learning purposes.

2) The design of curriculum should be well planned. The software and hardware may affect the overall teaching and learning effect. The inquiry function and operational training are the key points to be concerned in developing the e-learning platform.

3) Encouraging students to participate in activities, promoting high-level reflective thinking and critical thinking, enriching online interaction, and promoting and researching the developing of e-learning.

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WIKI-BASED PROJECT IN ENGINEERING EDUCATION: EVALUATION AND CONSIDERATIONS FOR EFFECTIVE USE

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Abstract

Although Web 2.0 communication tools like blogs and wikis have been used for supporting collaborative learning there are not many reports about implementation of that resource on engineering in Brazil. This paper reports on the use of Wiki as an online didactic tool to provide new opportunities to pro-active and collaborative writing in engineering education. The project was developed to support a collaborative space discussion for specific topic of the discipline Reinforced Concrete Structures at 4th year of Civil Engineering course. The wiki was created in Wikispaces platform (http://www.wikispaces.com/). A total of 43 students were invited to participate in four-week online activities and they were monitored during their participation. The perspectives of students on this experience were gathered by informal interviews, analysis of the content and number of comments made by students and statistical analysis of the data collected from the Wikispaces platform and Google Analytics (http://www.google.com/analytics/). Some students related that wiki was a nice tool for collaboration work and file sharing. However some students also reported that the wiki's development it was difficult. Finally, it is presented in this paper some considerations for effective use of wikis as collaborative writing tools in engineering education.

Keywords: *Engineering education; wiki-based project; collaborative learning environment.*

1. Introduction

The dizzying development of Information and Communication Technologies (ICT) during the last two decades encouraged the permanent presence of digital devices (personal computers, laptops, tablets and smart phones) in humanity's daily life changing the way people access and use information, access and use services, and conduct commerce [1][2]. Especially in Brazil, many more young people, i.e., students from 16 to 24 years old have accessed the Internet for reading and learning lately. According to Fundação Telefônica final report [3] the main activities performed by Brazilian youth of today on the Internet are: communication activities (37.3%), leisure activities (29.6%), reading newspaper and magazines and gather information (28.7%) and learning and education (28.1%).

Considering that context, the traditional teaching model widely used in higher education institutions in Brazil needs for an innovative model to accompany the arising changes and to attend the needs of today's society. The most popular approach based on the teacher-centred is so familiar for Brazilian's professor that sometimes seems to be the only way to teach. That educational approach has fulfilled its role and has been responsible for the education of our ancestors. Meanwhile, innovative practices based on computational resources such as chats, videos, animations, simulations, virtual labs and collaborative environments can be added to teaching and learning process [4]-[7], but it is necessary to encourage the application of those resources in the educational sector in Brazil.

In this work it will be presented the considerations about the particular use of wiki to civil engineering education. The purpose of the project was to provide new opportunities to pro-active and collaborative writing in engineering education. The paper starts by discussion about online collaborative learning which has been focused on the collaborative use of online and social media. The second part will cover the methodology of the study. The results are demonstrated in the third part. Finally, conclusions a future work are presented.

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2. Online Collaborative Learning

Collaboration involves participants working together on the same task and requires mutual engagement of participants and intellectual efforts to solve a problem together. Many factors can still wield enormous influence within collaboration group such as student characteristics, group composition, and task characteristics. [8] [9]. As a learning strategy, cooperative learning environment involve intellectual interaction in the learning process and differences in knowledge, skills, and attitudes among collaborators become clear. However, collaboration can have powerful effects on student learning, particularly for low-achieving students because they support each other by co-constructing and sharing knowledge within their learning group, i.e., knowledge is shared and acquired during communication, negotiation, and production of materials [8]-[10].

The use of the Internet on learning is more intensive, especially after the emergence of Web 2.0 technologies. Some advantages of using Web 2.0 in education are to increase access for students to education, responding to their lifestyles through flexible learning opportunities [11] and to provide other possibilities for communication and transmission of knowledge that may favour the interaction and collaboration [12] [13]. There are many different types of online learning technologies available to teachers. Before making decisions concerning appropriate use of technologies, it is helpful to look into learning process and tools that support process' activities. In general, learning technologies can be divided into two categories: institutionally supported and open access. Learning Management Systems (LMS) are institutionally supported technologies. They are a centralised, closed system that is secured behind authentication and can only be accessed by an institution's staff and students. Blackboard (www.blackboard.com) and Moodle (www.moodle.com) are good examples of LMS. On the other hand, open technologies can be set up or used by anyone. They are usually referred to as Web 2.0 or social media and some examples include: Facebook (facebook.com), Twitter (twitter.com); YouTube (youtube.com), Flickr (flickr.com), blogs and wikis [9] [11] [12]. The term blog comes from the bend of web log. It is an online platform and can be imagined as a type of online diary. They are usually open to the public. The posts can be chronologically presented, i.e., newer posts are at the top of the page. Wiki is a collaborative tool which allows users create and edit hypertext easily. Many different medias can be embedded into a wiki (images, graphs and videos) and external sites can be conveniently settled up by hyperlink [8] [9]. All members or participants of the wiki have permission to visualise and comment the posts, but it is possible to specify who is allowed to edit the posts. Most useful application of wiki is as a tool for creating group projects [13].

Collaboration takes place with communication and interaction. In the education domain, a project based on collaboration depends on the project management, resource management, ideation, decision making, archiving and presentation. Wikis platforms provide an appropriate resource management, archiving and presentation. It is possible to control changes because the platform saves all the text versions. Furthermore, wiki administrators can choose different privacy settings to determine specifically who can view and edit content on a wiki. Like early mentioned, on wiki platforms it is possible to construct documents with different Medias embedded. It also has available a simple but complete word processor to edit texts. In this case wiki became an online working environment supporting creative group processing enabling students to interact, develop ideas, generate outlines and to create the final projects [12] [14].

3. Methodology

3.1. Participants

The participants in this study were forth-year university students from a face to face Civil Engineering course. A total of forty-three students were invited to participate in four-week online activities - from November 23rd to December 19th, 2014.Three students did not fill in the curse, third-five percent of the participants were female and sixty-five percent were male. All of them were enrolled in Reinforced Concrete Structures which is a compulsory discipline in Civil Engineering course. Students were divided into a five groups and randomly assigned to a group. All students had experience with working in groups, but none of them were familiar with wiki-based collaborative writing. Participation in the wiki project was a complimentary part of the course as homework task.

3.2. Wiki tool

Wikispaces Classroom (http://wikispaces.com) is a social writing platform for education. It was chosen because it is suitable for collaborative learning, i.e., students you can use it easily; teacher students can communicate and work on writing projects alone or in teams; it provides assessment tools give teachers the power to measure student contribution and engagement in real-time; and, Wikispaces Classroom works on modern browsers, tablets, and phones. The main features of Wikispaces Classroom platform are (http://wikispaces.com):

- Create a safe, private network and individual or group assignments in seconds;

- Schedule all tasks and choose to set assignment start and end dates;
- At the end of the assignment, automatically publish projects to the entire class or students, parents, or others in their community;
- Monitor complete history of student discussions, writing, and file uploads;
- Watch student engagement in real time;
- Report on contributions to pages, discussions, and comments over time;
- Focus on particular students, projects, or view reports across their entire class.

At first, each team starts with a "home" page but it is possible to create more pages. The content can be easily collaboratively edited on the platform using the visual editor. It is possible to embed content from around the web, including videos, images, polls, documents, and more.

3.3. Procedure

Technical features of wikis were introduced to the students during the first week of the project. Students were also supplied with lectures on collaborative writing and wiki-based project. The forty-three students were asked to register on Wikispaces web environment and invited to participate in project. Figure 1 shows some wiki members where the organizer is highlighted. The project was introduced to students on the web environment, comments were encouraged and some questions about the Wikispaces could be answered.

Figure 2 presents the 5 groups assigned on the Reinforced Concrete Water Tank project. A total of forty students enrolled in the environment. The researcher randomly assigned participants to wiki groups and asked them to share their researches about the group topic with each other through structured wiki exchanges. For each group of students was established a specific topic of the subject Reinforced Concrete Water Tank (Table 1). Students had to work together during a four-week period in order to create a wiki document. All groups were asked to develop an informative wiki about their topic containing the following: (1) an overview, (2) theoretical rationale, (3) advantages, (4) disadvantages, (5) and practical applications. Students were provided with articles and bibliographic information, i.e., books available at university library. In addition, they were informed that seeking and using additional resources were allowed.

It was timetabled two tasks for each group, the first task (overview, theoretical rationale) started on November 29th and the maximum deadline for publications was December 8th, see Figure 3. The second task (advantages, disadvantages and practical applications) was timetabled to start on December 9th and the maximum deadline for publications were December 14th, see Figure 3. The final feedback was published during the last week of the project.

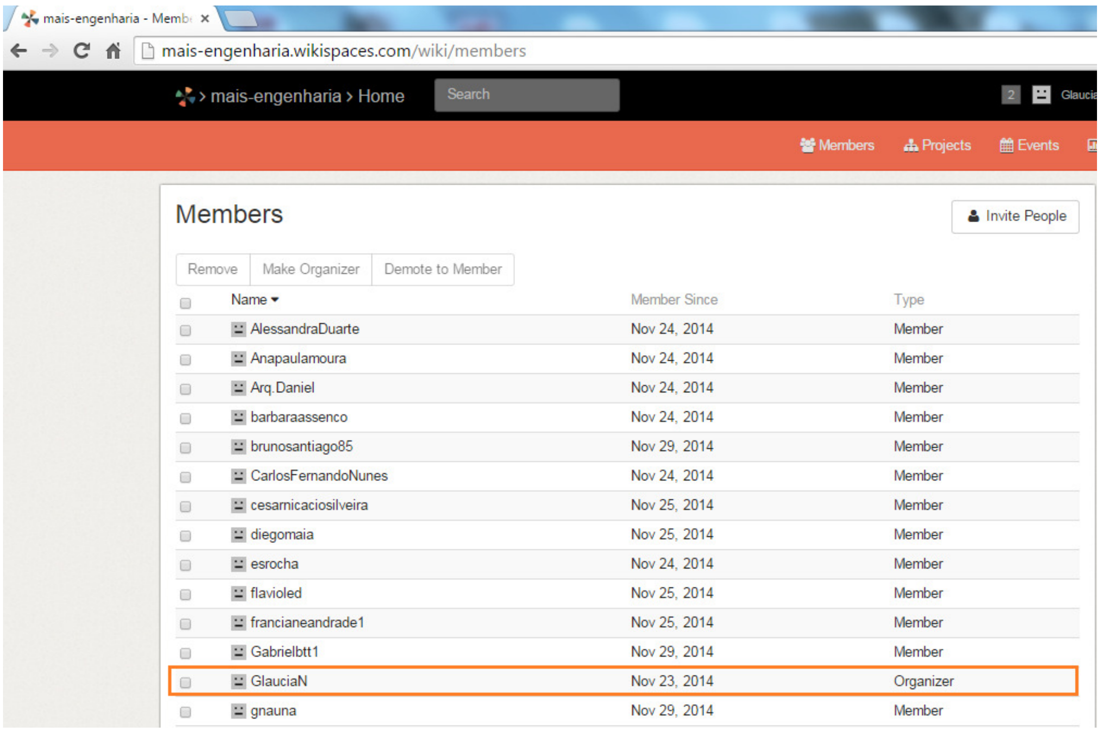

Figure 1. Members of Water Tank project.

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Table 1. Topics of Reinforced Concrete Water Tanks.

Group	Topic
1	Pathologies of concrete water tank
2	Precast concrete water tank
3	Underground water tank
4	Elevated water tank
5	Ground water tank

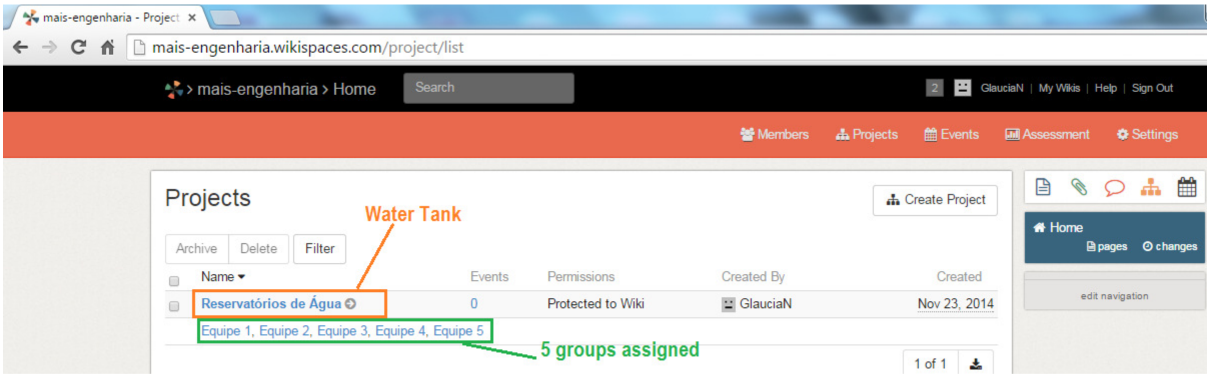

Figure 2. Groups of Water Tank project.

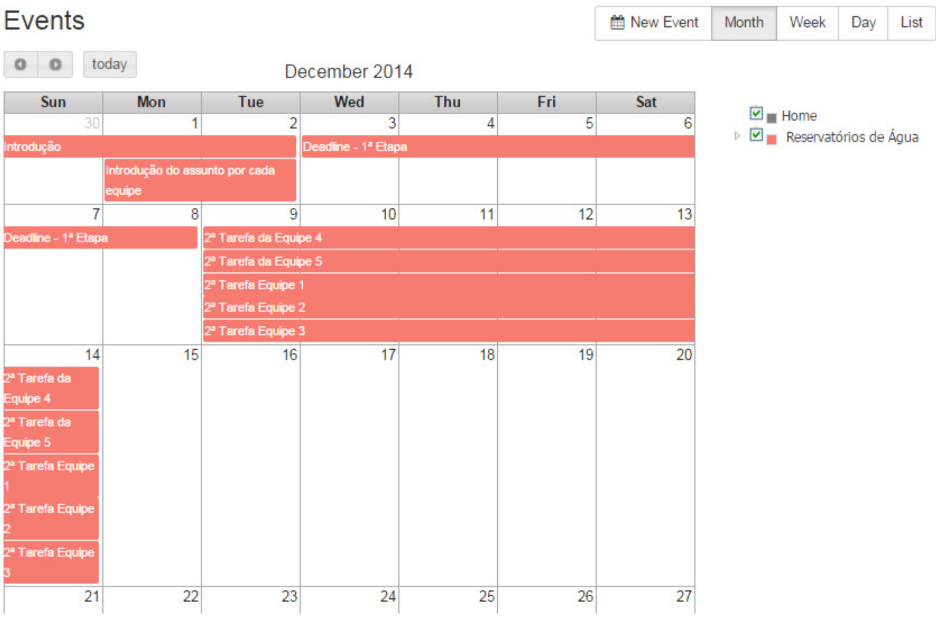

Figure 3. Timetable for December tasks.

4. Result

Two data collection instruments were used in this study: statistical analysis provided by the Wikispaces and Google Analytics; and analysis of the comments, messages and informal interview. Number of revisions, number of comments and page views were data considered from Wikspaces platform. All participants in the project wiki were allowed to access any page but, they could edit only the pages of their group. The pages of Reinforced Concrete Water Tank wiki project were accessed 3327 times; there were 104 revisions and 132 comments. The Group 5 home page was the most visited as shown in Figure 4. The revisions and comments concentrated on the second and third weeks of the project, Figures 5.

Table 2 presents the participation of each student in the wiki project. The participation of each student was evaluated by the number of revisions and comments they made. Groups 5 and 1 had more revisions and comments and their members also had more effective participation, Figure 5. The wiki pages developed by

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Groups 5 and 1 were complete with all required information; they also had organized structure and several media resources like images, videos and links for extra information.

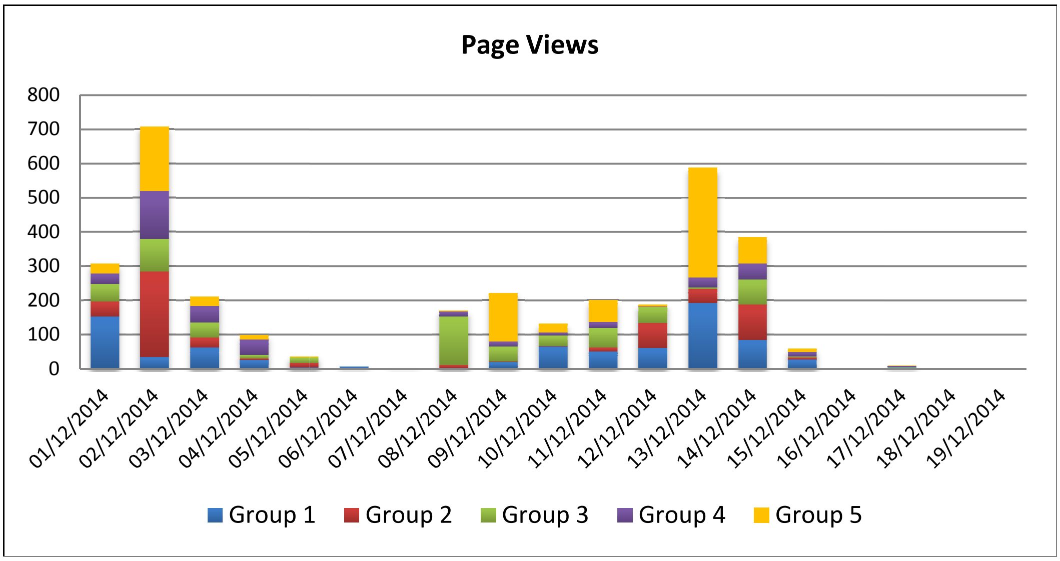

Figure 4. Group page's views.

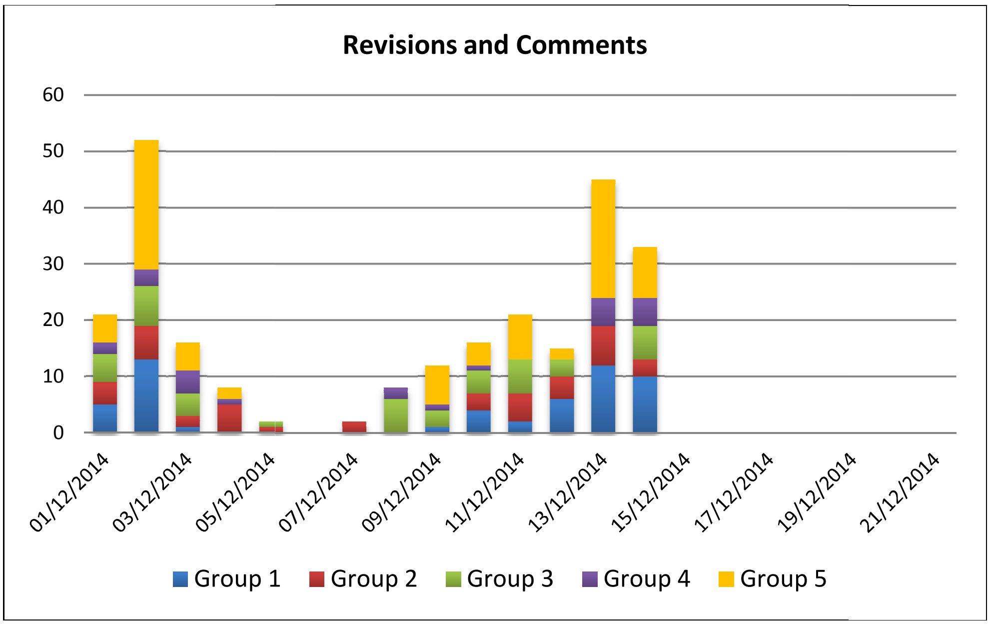

Figure 5. Revisions and comments for each group.

Table 2. Students' participation by group.

Participation (%)					
Student	Group 1	Group 2	Group 3	Group 4	Group 5
1	16,67	14,29	51,11	16,67	31,40
2	3,70	30,95	4,44	0,00	37,21
3	9,26	21,43	0,00	25,00	5,81
4	0,00	0,00	11,11	0,00	4,65
5	3,70	11,90	13,33	16,67	0,00
6	9,26	11,90	20,00	29,17	20,93
7	44,44	7,14	0,00	12,50	0,00
8	12,96	2,38	0,00	0,00	0,00

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According Google Analytics reports average time per session was 00:10:13 and average of accessed pages per section was 11.67. The Google Analytics report also shows that the minority of students (23.81%) accessed the wiki through the university network services.

The comments were considered into two classifications: low to medium level of collaboration and high level of collaboration. High level collaboration comments (18.37%) referred to wiki requirements, organization and collaboration. Low to medium level of collaboration (81.63%) referred to images, format of pages and subpages, addition of information, links, reference and spelling errors. Some students related that wiki was a nice tool for collaboration work and file sharing (Example 1: " Despite not having participated in other projects via internet I enjoyed the wiki project because I think the students are encouraged to collaborate more"; Example 2: "I enjoyed participating in the project, the best part was being able to choose the time to do the tasks"). However some students also reported that the wiki's development it was difficult (Example 3: "I think it is difficult to understand the Wikispaces platform, I had problems setting up the pages and insert pictures and videos".

It was encouraging to know that most students (29/40) had effectively participated on the project although 9 of them had a poor participation (less than 10%).

5. Concluding Remarks

The main objective of this study was to explore the implementation of a wiki task in higher education, and more specifically to observe the level of collaboration between students in wiki environment. Despite the potential of social media, specific challenges were noticed when new tools and methods are implemented in higher education practices. The first one is that courses often consist of groups that may reach high-level collaboration, and others in which shared work remains superficial or does not exist. Measuring collaboration by counting the number of editors per page is not enough in the educational setting. In this study, for example, the groups 2 and 4 had more editors than the groups 1, 3 and 5 but, they also had a poor score. It is better to measure the degree of intensity of collaboration among the members alongside the number of editors per page [15].

Another important challenge was observed in accordance with Waycott *et al.* [16]. The authors emphasize that the use of social technologies in higher education could introduce new tensions for students and teachers when (1) students make their work visible to others, (2) teachers challenge the rules and established practices associated with university assessment and (3) introduce new practices and pedagogical approaches. Meanwhile, learning opportunities inside and outside classroom (diversity, technology, collaboration, community service, etc.) enhance learning and students are motivated and satisfied at schools that actively promote learning and stimulate social interaction [17]. It is appropriate to students be sure they are comfortable with how they represents themselves in online environment so, it is convenient educate students about taking care when publishing their work on social medias [16]. Teachers should consider negotiating with university the rules for assessment and paying attention on pedagogical aspects related to online learning.

Finally, people are very competent in using ICT's in their daily lives but they need support to integrate technologies into teaching and learning process. Before introducing technological tools in their classes, teachers have to be sure about the importance of pedagogy over technology. In this way, some suggestions are presented: (1) technology will not automatically bring benefits it is necessary to rethink the pedagogy; (2) in general, face-to-face content and teaching strategies will not work in the same way in an online context without any adjustment or planning; and (3) students are not always familiar with using technology in their learning process, they need support.

The results may only be representative because this study was conducted with a small convenience sample (n = 40) with participants from just one course. The interviews were conduced with a small group of students (10). Additional qualitative analysis is necessary on this topic. In order to go more into in detail student view should be conduced. For the future work, students could be asked to answer a detailed questionnaire about the experience in the wiki project. The assessment also could be improved, perhaps including peer assessment.
And, the last one, the sample size could be enlarged.

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Presenter: The paper is presented by Gláucia Nolasco de Almeida Mello.

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Usability of the UML4ODP for a Technological Specification of a Distributed Teaching Embedded Systems Environment

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Abstract

The present work is part of the research that we have been working on for many years and which concerns the design and development of remote laboratory systems (more specifically about distance Lab Work).
In response to the resolution of problems related to the distance Lab Work, we have proposed in our previous works the specification of a distributed environment that will help to generate distance Lab work Supports for teaching embedded systems. This has been called "a Tele-LabWork System Environment Generator for Teaching Embedded System" or "TeleLWS_EG", for short.
The ODP- RM model (Open Distributed Processing - Reference Model) proposed by the ISO (International Organization for Standardization) provides five viewpoint languages for specifying open distributed system. The viewpoints are: enterprise, information, computational, engineering and technology viewpoint.
The five viewpoints of the RM-ODP model were used to specify the architecture of the TeleLWS_EG system. The instantiation of these viewpoints on the actual standardized educational technologies has allowed us to prove their existing gaps. In particular, we found the absence of a meta-reflection on the life cycle of the learning system and consequently the non-inclusion of the business and technological viewpoints.
The technology viewpoint in the RM-ODP model defines the environment of implementation and deployment of systems using the best current technologies, standards and products.
In this paper a combined use of RM-ODP and UML4ODP profile will enable us to specify the technology viewpoint of the TeleLWS_EG system.

Keywords: ODP-RM, UML4ODP, Technology specification, Embedded System, Distributed Environment, Distance lab work, online laboratory.

1.Introduction

We recall that the main objective of this paper is to perform (according to the ODP-RM [Open Distributed Processing - Reference Model]) a technology specification of a distributed environment that will help to generate Distance Lab work Supports for teaching embedded systems. We have called this environment "a Tele-LabWork System Environment Generator for Teaching Embedded System" or "TeleLWS_EG", for short.
This technology specification is produced based on the engineering specification that we have done in [1].
The technology specification describes the implementation of the ODP system in terms of a configuration of technology objects modeling the hardware, software and network components of the implementation.
Technology objects, such as those considered as an implementation of the corresponding engineering objects, will be deployed on the different clients and servers of the TeleLWS_EG system.In the follow sections, the technology specification of these clients and server will be detailed and expresses with UML4ODP.

2. An Overview of the Technology Specification of the TeleLWS_EG in UML4ODP.

Table 1 shows the schematic profile UML4ODP that summarizes the UML extensions for technological language of the ODP_RM model [2].

Table 1. Technology language Icons

«TV_Object»		«TV_TypeObject»		«TV_Implementation»	
«TV_TemplateObject»		«TV_ImplementableStandard»			

To improve the clarity of the diagrams in this paper, the icons shown in this table will be used to represent the instances of the corresponding stereotypes.
The left part of figure 1 describes the architecture of the deployment of the system by showing the various types of technological objects that will be used to implement it, and how these objects should be interconnected together. The diagram shows that there will be three types of computing resources (computers, application servers and enterprise servers) and three types of communication media (LAN, WAN, and WWAN) [1, 3].
The right part of figure 1 describes the actual system, with concrete instance specifications of the nodes shown in the upper part of the diagram, showing the technology objects that will comprise the system, and how they are connected.

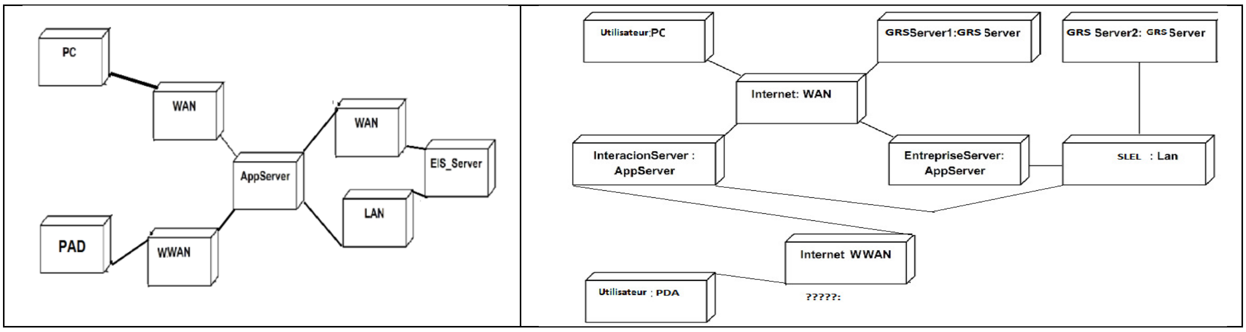

Figure 1. Node technology configuration overview

3. The client side technology configuration: case of mobile devices.

In UML4ODP, the "ClientTier» structures can be specified both at the type level and at the object level. The diagram in Figure 2 below shows the internal structure of the the "ClientTier» node used in the TeleLWS_EG system. Many technology objects That constitute the "ClientTier» node are generally GUI that allows the user to access to the TeleLWS_EG system.
These objects represent usually a thin client application software which is extracted from the primary resource library of the TeleLWS_EG system.
Depending on the equipment installed at the client node, there is a wide variety of thin client software that can be used: we can use a web browser with a standard desktop as we can use a wireless internet browser (WIB), supporting Wireless Markup language (WML) with a mobile device Like a Personal Digial Assistant (PDA).

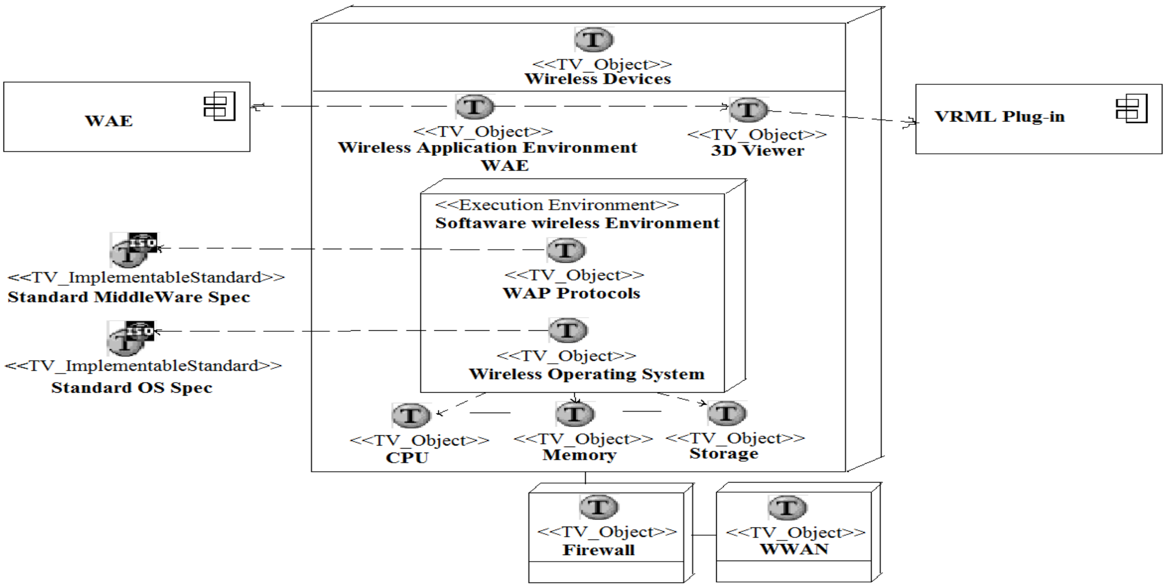

Figure 2. The internal structure of the the "ClientTier» for the case of mobile devices

As shown in Figure 3, in our particular context related to the teaching of the automated system the browser of the client node is requested to visualize the virtual mechanical part of the DLWMPrJ (Distance Lab Work Management Project, cf 5.) platform using a "3D viewer". This virtual mechanical part which is modeled in a 3D

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language (VRML) as a modular robot will be combined via a communication protocol with a real embedded control device during handling of the platform of TéléTP.

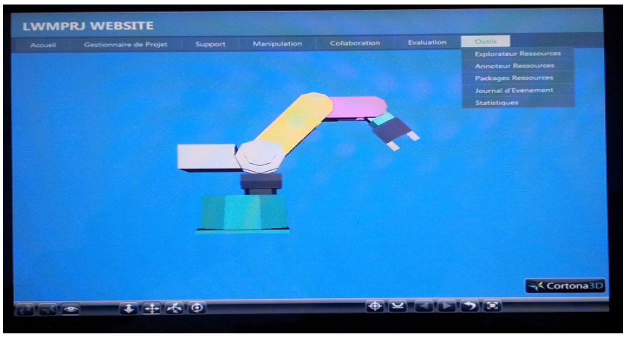

Figure 3. Mobile Client supporting two Technology objects: Wireless Internet Browser and a VRML

WAP (Wireless Application Protocol) is proving the most optimal communication protocol that allows access to InteractionServer node (Web Server) via Internet.

4. The web server technology configuration.

As our learning environment TeleLWS_EG is composed of four sub personalized generic environments (core, LWMS, LWMPrJ and LWMPrD), each environment has its own web interface.
In this paper, we are specifically interested by the LWMPrJ environment.
The prototype of the website LWMPrJ is presented in Figure 4. It shows the the facilitator, the administrator and the learner user interface.

Figure 4. The view of the the D LWMPrJ interactive Environment delivred by the WebServer

This environment includes more specifically the tele-manipulation environment which is used for practical activities related to the embedded platform.
The web server of our learning environment (TeleLWS_EG) requires the technological configuration shown in Figure 5 and which incorporates: communication support, connection devices, the software components of the server environment (operating system, hosting web server, the runtime engine) and the TeleLWS_EG web interfaces. These essential elements of this technological configuration allows the diffusion of TeleLWS_EG system.
The technology objects that represent the presentation objects and that support the MVC architectural model are deployed on two nodes: the WebServer and The ApplicationServer nodes.
The system functions related to the presentation and to the interaction with the user and that must be provided by the TeleLWS_EG system are assigned to this type of objects.
These Technology objects allow the user to interact with the business objects in a secure and intuitive manner.
An interaction object is in fact an aggregation which is composed of three types of objects according to the MVC Model (Model-View-Controller): the controller object, the model object and the view object.
The model classes are placed in a separated "assembly" to be used in different applications and to test the logic of the application more easily and without passing through the user interfaces. The Model Classes are used from

the MVC controllers. They are instantiated in the called controller actions in order to call their methods that can display data in the MVC views.

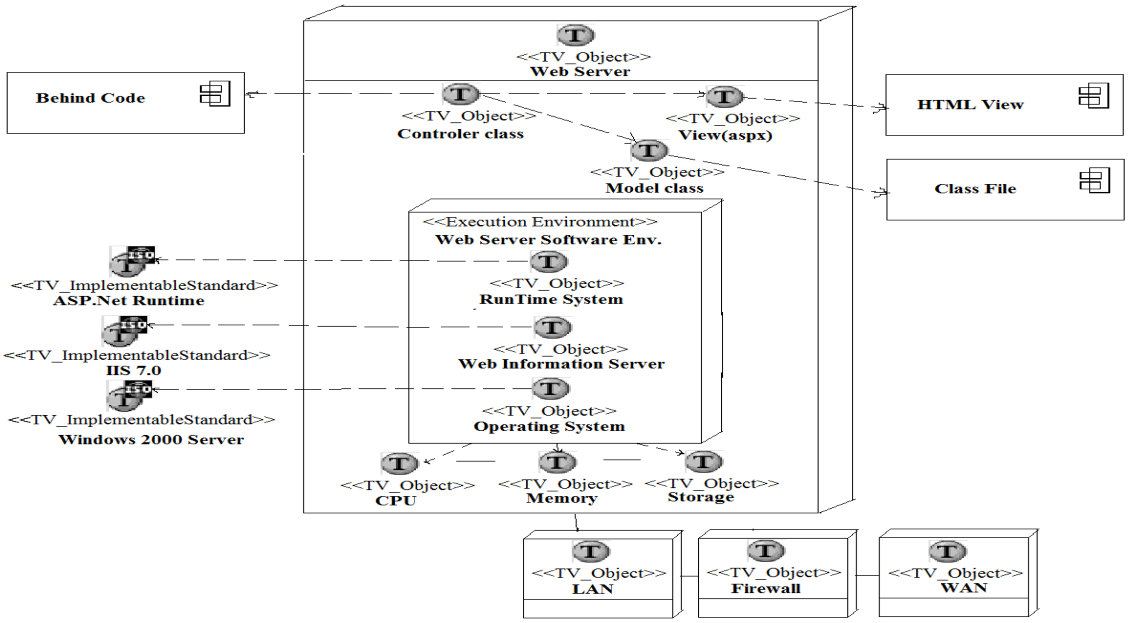

Figure 5. Technology object configuration of the WebServer

The controller is a control object which is always coupled to a view object. It handles user requires coming from the client workstations and orders a business or a model object to respond to the user's request appropriately.

5. The application server technology configuration.

The technology objects corresponding to the business computational objects and the interfaceGRS's manager objects are deployed on the EnterpriseServer node:

- These objects represent the business logic of the TeleLWS_EG system.
- The system calls to these objects are performed by the ClientTier via theInteractionTier (WebTier).
- If necessary the EnterpriseTier interchanges with the recording layer (RMS:ressources management system) to access to the resources invoked by the said calls.

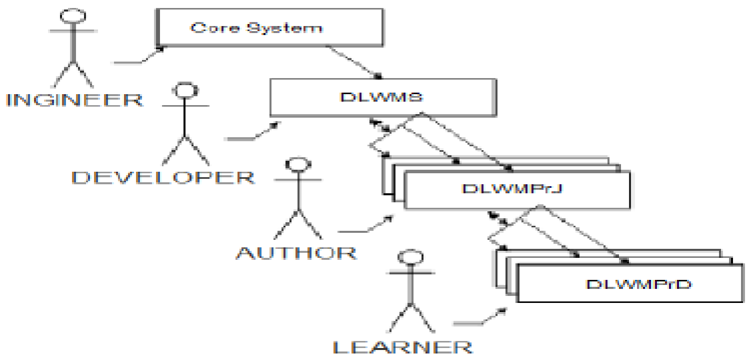

Figure 6. The four levels of the TeleWS_EG's cascade architecture

These business objects are responsible of the production system of the TeleLWS_EG's aggregation resources that are organized in four levels of a cascaded architecture [4] as shown in figure 6. These objects are particularly global: The first level of this production cascade which is represented by the basic system " TeleLWS_EG Core " allows us to produce the objects of the second level. These ones are really a set of distance labwork platforms and they are technically known as DLWMS (Distance Labwork Management System). The DLWMS are used to generate the objects of the third level of our cascade that are called DLWMPrJs (Distance Labwork Management Project). The DLWMPrJ which is an application software used as an environment to remotely practice Lab works on embedded system. It is used to produce a set of aggregated products that will constitute the fourth level of the cascade. These products are the results of the practice activities performed by

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the different actors concerned by the execution of the DLWMPrJ. These products are assembled in a set of portfolios (portfolio) or DLWMPrDs(distance Labwork Management Product)[1].
One of the most important job performed by the server is the one that is made by the central funtion of the LWMPrJ application. This function is constructed by the author as an aggregation of pdagogical acts. This function includes the scenario monitor that contains the instructions related to the control the sequencing of acts in accordance with arrangements specified by the LWMPrJ scenario.
From the point of view of operating system and installed services, as shown in the figure 7 the application server is a role of an expanded server within the Windows Server 2012 operating system.
This operating system provides the following components:

- An execution environment with deployment functionality and an efficient management of high-performance business application server.
- The Microsoft .NET Framework: based on the Common Language Infrastructure (CLI) standard which is independent of the used programming language.
- a new convivial wizard for adding role services and functionalities needed to run our business applications.

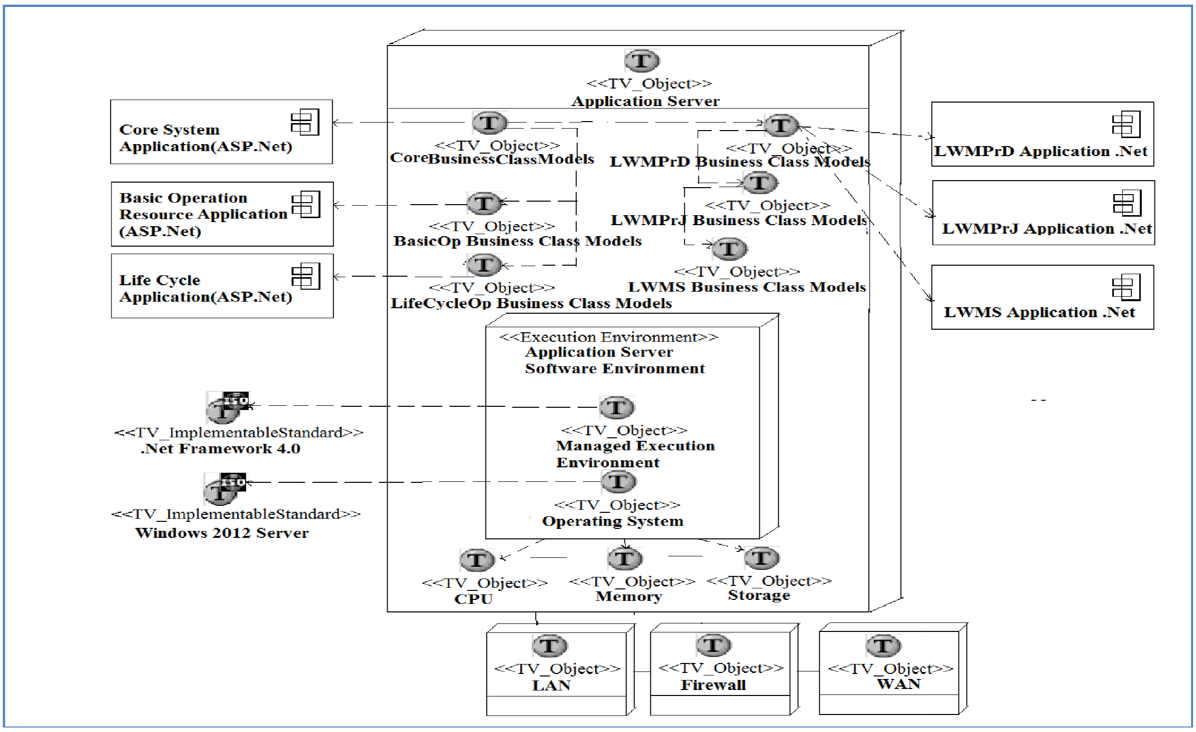

Figure 7. Technology object configuration of the ApplicationServer

6. The technology configurations of the Resource Management Servers (RMS)

As we wrote earlier, the resource tiers (RMS: Resource Management Servers) of the TeleLWS_EG system contains multiple access servers like : the library access server, the semantic library server and the access server to the embedded control devices of the distance Labwork platform [5].
The following three sections will detail in terms of technological objects the internal configuration of each server type.

6.1. The technology configuration of the library access server.

The first server is used to deploy the managers of the different types of the resource libraries that contain the entire information system of the TeleLWS_EG, except the managers of the embedded system control devices that are deployed on another node.
These libraries include different types [6] of resource aggregations: 1) the primary resource libraries include documents and tools (D, T), Users (U) and operations (O), a simple text editor that lets create a control code to be executed by the control device can be among the tools of these libraries; 2) the secondary resource libraries comprises the interfaced resources (the interaction objects) resulting from the combination of a control component or a HMI with a primary resource or from the aggregation of primary or interfaced resources; the 3D

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Web Based robots that are coupled with control devices to teach embedded systems, can be considered as secondary resources; 3) the tertiary resource libraries grouping the most important enterprise objects of our TeleLWS_EG system: Core system, DLWMS, DLWMPrJ and DLWMPrD.
These different types of libraries are implemented as Microsoft SQL Server data bases. Today, there are many technologies allowing the implementation of distributed applications: DCOM, CORBA, Java RMI, the framework ".NET" or XML-RPC. We have chosen ADO.Net in order to realize communication between business applications resource libraries of the TeleLWS_EG system because of its complete independence with any programming language and any operating system.

6.2. The technology configuration of the semantic library server.

As shown in figure 8 a second server for managing the semantics library of the TeleLWS_EG system. This server contains several semantic repository managers.

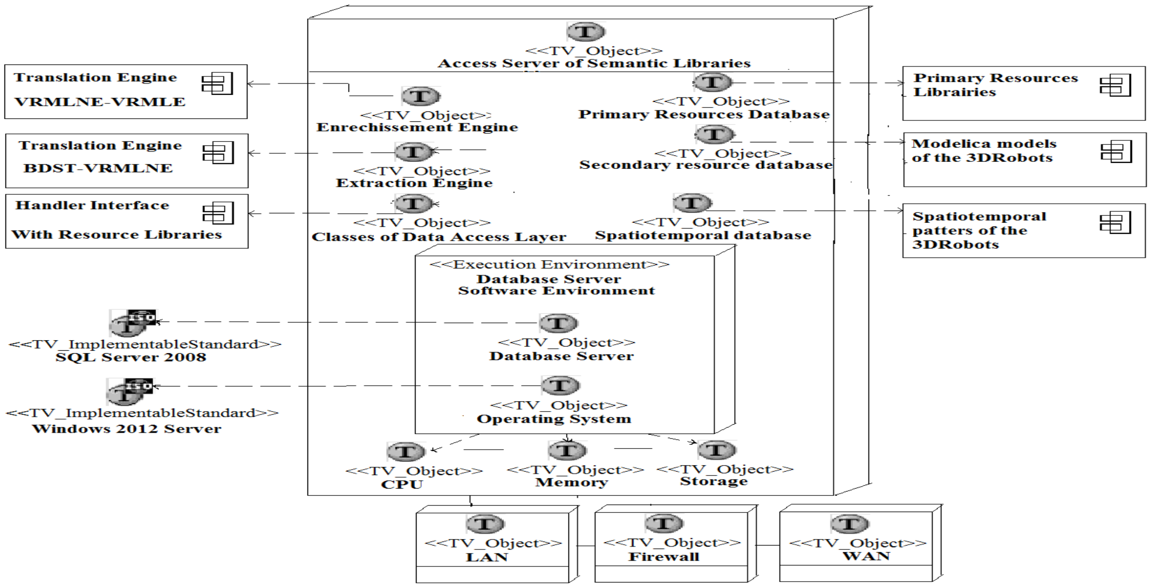

Figure 8. Technology object configuration of the semantic library server

The main managers that are deployed on that node are those of ontologies [7] written in SOCOM (Software Component Metadata). We have adopted this semantic representation to construct the semantic repositories that describe the system resources and their administrative and technical context of use.
One of the specific ontology that was used has been defined as spatiotemporal patterns[7] which combines the concepts of SOCOM[8] and MADS[9] formalism to describe a 3D Semantic Data Library that produce descriptions of 3D robots for distance Labwork.
About the choice of technology that will be adopted for the implementation of semantic information of these spatiotemporal patterns we can implement them as an ontology or as a relational model. Each implementation has its own advantages and disadvantages.
In our case we have adopted a mixed solution using enrichment semantic information (reverse engineering method) and the relational model metadata together. Figure 9 shows the schema of this relational database.

SimulateurRobotPolyArticulé(SimRobPA*ID*, ComponentLanguageType, AgregationMethode, Coupling Potential, Coupling Level, SoftwareLayer)
ComposéDeCompCMLR(SimRobPA*ID*, CompCMLR*ID*)
ComposantCMLR (CompCMLR*ID*, TypeComposantCMLR, PositionComposantCMLR)
PossedeComportement(CompCMLR*ID*, ComportementCompCMLR*ID*)
ComportementCompCMLR(ComportementCompCMLR*ID*, TypeCoportementCompCMLR, ScriptComportementCompCMLR)
PossedeForme(CompCMLR*ID*, FormeCompCMLR*ID*)
FormeCompCMLR(FormeCompCMLR*ID*, Geometrie, Apparence)
PossedeConnecteur (CompCMLR*ID*, ConnecteurCompCMLR*ID*)
ConnecteurCompCMLR (ConnecteurCompCMLR*ID*,*TypeConnecteur*)

Figure 9. Schema of the relational database recording the semantics of spatiotemporal patterns

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Pending the development of a data converter to handle changes in the structure of the metadata patterns and for the synchronization of data, we have populated the database manually by using metadata instances related to spatiotemporal patterns of polyarticulated robots.
Our approach for the 3D visualization of spatiotemporal patterns simulators poly articulated robots is based on the idea that the semantic data of the relational database can be extracted by analyzing the associated Modelica files "* .mo" .In [10] we have detailed our proposed architecture.
The main components of this architecture are:

- The extraction Engine that consists of a set of extraction rules for the transformation of the pattern of the relational database schema to enrich VRML.
- The enrichment Engine that consists of a set of rules enrichment, it allows the integration of semantic extracted from the Modelica file in VRML scheme not rich.

6.3. The technology configuration of the control devices server.

A third server for the management of the control devices embedded systems: due to many reasons related to the genericity of the distance labwork scenarios and to the specificities that characterize access to the control component of the embedded automated systems, we have chosen to deploy their manager on an independent server as shown in Figure 10.

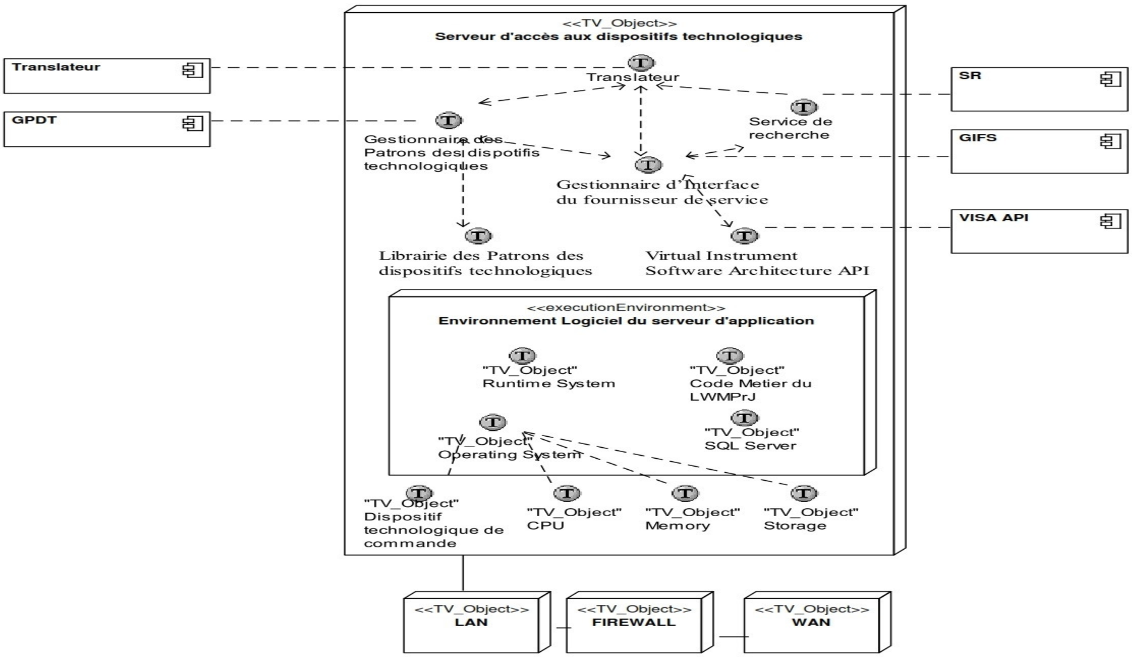

Figure 10. Technology object configuration of the control devices server.

In fact, the manager of these devices is a very specific tool that ensures mainly the functions of referencing, research and access to these control components.
The Control devices of the embedded automated systems, are declared in the Labwork scenarios of our Generic environments (PLC, microcontroler etc.) as Universal Resource Locators (URLs) to the desired devices like any other object (document, script, etc) on the Web [11].
To ensure the genericity of these scenarios, it is necessary that these URLs localize the control devices and their expected functionalities and not the address of the labwork platform server because in this case the scenario would be specific to a single labwork platform in the world.
Once a new type of a control device or an extension of an existing type is physically installed, the administrator of the labwork platform uses Control device Interface
Management Tool to declare it at the device access server by creating a new pattern or, respectively, a pattern derived from an existing pattern (to limit the declaration of additional components and functionalities) and thus make it available to users.
Once the pattern is created, the administrator must declare (by using the manager)the links between the functionalities described by the pattern and the physical hardware components [12].

7. Conclusion

The instantiation of the RM-ODP technological point of view that was performed in order to achieve the

specification of technological objects (hardware, software, and network components) that will enable the implementation of online laboratories can be used as a tool to conduct the development of new standards that will be used to formalize the specification and modeling tasks of the online laboratories components;
The IEEE standards association has approved in June 2012 the creation of a working group on online labs P1876 ™ (Standard for Networked Smart Learning for Online Laboratories).
The work that we have presented in this paper is a contribution in the development of this P1876 standard that we have shared with hundred of: researchers, teachers, designers and learning equipment providers.

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E-teaching and Digitalization at BME

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Abstract

Our research focused on the results of a project development entitled "E-Teaching Culture and Digital Content Development at BME" that took place between 2013-2015. It aimed at developing content, methodologies and services related to the competitiveness of higher education, structural changes coming from the Bologna Process and meeting the challenges of knowledge-based economies. The relevant fields included updating presentation techniques and instructional methodology. These areas were particularly important from the viewpoint of the topic. We intended to present that visual learning may provide opportunities to use parables that are able to improve the efficiency of human learning. This learning process is currently based on traditional verbal communication and as such hindered by time constraints and information pressure. Developing curricula presented challenges in the fields of digitizing, multimedia editing and on-line publishing. Meta-data structure, SCORM conversion and formats matching the relevant criteria were defined as required by e-learning. Empirical analysis was performed on the use and efficiency of the new SCORM learning materials. Thus, the results of the research pointed out a number of good practices. These can be used as "working" innovative solutions that take into account and adapt to the learning habits, attitudes, new student roles. These solutions also adapt to the expectations of the higher education students.

Keywords: *ICT, e-content, digital material, virtual learning environment*.

1. The starting point

The project „E-teaching Culture and Digital Content Development at BME" was implemented between 2013 and 2015. This project aimed at developing contents, methodologies and services related to the competitiveness of higher education. It focused also on structural changes coming from the Bologna Process and meeting the challenges of knowledge based economy. The project rooted in the idea that the strategic goals of the university as well as those of vocational training presume the continuous development of the quality and excellence of teachers. These teachers-researchers are essentially independent of the limitations represented by subjects or faculties. The relevant fields included (while not being limited to) updating presentation techniques and education methodology.

Another reason justifying the project is that education at BME essentially still relies on traditional educational forms and methods. Only few practical examples exist that illustrate the use of ICT in learning and teaching. One of these is the work of the Department of the Department of Technical Education, the body providing the institutional background of the project. Here the majority of subjects are taught in the Moodle framework system. However, most of the curriculum is not yet digitized and the same applies to the entire university [3].

2. The realization of the Project

In the framework of the project, the development of digital curricula in English and Hungarian for 27 subjects was planned. 10 curricula were related to subjects in the fields of technical sciences, natural sciences and mathematics (abbreviated as MTMI from Hungarian) and 17 to non-MTMI subjects. Altogether 10 curricula were developed in English, 4 ones related to 4 MTMI subjects. The relevant credits totaled 77; from these, 26 ones were foreign language credits, corresponding to 33%. The developed curricula are used by about 2000 students. Another project task was to extend the use of the Moodle framework system.

When selecting the subjects to be developed, the most important criteria were the number of students expected to attend the courses and the rate of extension represented by the digital content development activities by the given departments (e.g. mathematics for specialised teachers and MA students majoring as Teachers of Engineering). Teaching materials were developed to support the teaching and learning processes of popular programmes launched by the cooperating faculties. Teachers undertaking the development of digitized knowledge contents were directly involved in curriculum development. The following subjects were selected for the development project:

Table 1. Digital subjects materials

Faculty	**Subject**
Faculty of Civil Engineering	Roads
	Traffic Engineering
Faculty of Economic and Social Sciences	Financial Management
	Business Economics
	Accounting
	History of Economy
	Digital Education
	Education and Technology
	Learning Technique
	Learning and Career
	New Technologies
	Presentation
	Vocational Training and Labour Market
	Engineering Methods in Teaching
	Finance
	Introduction into Economic Policy
	Investment
	Learning in Digital Environments
	Autonomous Learning and Study Design
	English for Academic studies
	Written and Oral Presentations
	Learning for Sustainable
Faculty of Natural Sciences	Mathematics for Specialized Engineering Teachers 1.
	Mathematics for Specialized Engineering Teachers 2
	Mathematics for Specialized Engineering Teachers 3.
Faculty of Chemical Technology and Biotechnology	Chemistry
	Chemical Calculations
	General Chemistry

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Developing curricula presented challenges in the fields of digitizing, multimedia editing and on-line publishing. Meta-data structure, SCORM (Sharable Content Object Reference Model) conversion (converting contents into SCORM format with interactive elements) and formats matching the relevant criteria were defined as required by e-learning [3] [4].
The following figure shows a SCORM format developed digital learning materials (see figure 1.).

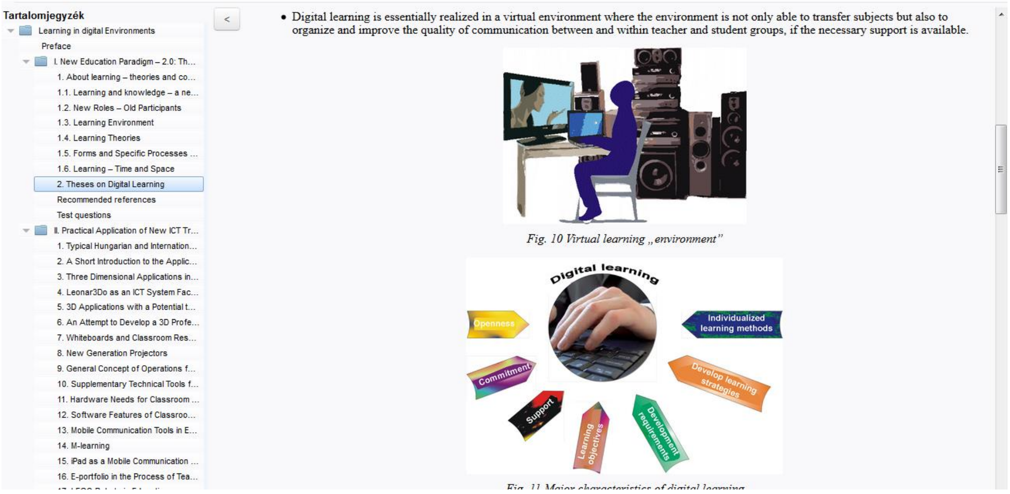

Figure 1. Digital learning materials in SCORM

When developing visual curriculum contents, the following new educational principles should be observed [6] [7]:

- Interactive techniques have become personalized and able to integrate several functions
- Mass mobile communication – everywhere and always
- Internet has become a ”public utility” – Wi-Fi
- Mass digitizing of learning subjects has become possible
- Learning is no more the simple reception of knowledge but also a chance to participate in collective content development
- Developed forms of human-machine interaction
- Independence from time and space
- Widespread use of mobile devices
- Possibilities of developing complex, medial ”learning environments”

Interests of students related to the principles above

- Improved and updated curricula
- Access to competitive learning contents
- Extension of flexible learning forms
- Contents and curricula for independent learning

Other important criteria:

- Measuring and evaluating student performance in the Moodle framework system
- Familiarizing participants with the measuring and evaluating algorithms and the related support options facilitated by new ICT solutions
- Introducing the options for practical implementation in teaching with special regard to electronic LMS and interactive systems.
- New possibilities for visual demonstration in curriculum, improving digital teacher competences and higher education teaching methodology skills.

Teaching teachers and researchers for higher education who will then possess the following skills and qualities [8] [9]:

- They can develop textbooks, teaching support materials or demonstration materials to promote the learning of their subject/special subject,
- Participate in digitizing and/or teaching the developed materials
- Familiarize themselves with the peculiarities of the digitized curriculum, support material or demonstration material,
- Familiarize themselves with the basic criteria of developing curricula, support materials or demonstration materials,
- Fully familiarize themselves with the demonstration options that may be built into the curriculum,
- Learn how to develop state-of-the-art ICT demonstration materials,

- Familiarize themselves with technical and methodological information and applications e-learning curricula are based on.

General and special dilemmas and questions:

- Habituation and routine
- Static interpretation of quality
- The opinion ”students are worse every year”
- The slogan ”gadgets are distracting”
- Is visual demonstration a target to be developed or a general tool?
- Is a picture a static piece of knowledge or a dynamising transformer?
- Does a picture multiply knowledge or illustrate a multifunctional system?
- Who can teach using pictures and how? Or is it the return to Orbis Pictus?

According to the soft opinions collected thus far, an excellent professional is ”able to communicate with students in a way that enables him/her to develop curricula that meet the criteria of the e-learning environment and teach these with modern methods”. This is why we may presume that students are affected by intensive visual communication at a measurable level, where this type of communication focuses the attention of students to the transferred knowledge in formal and informal ways that support network learning. Our analyses completed between 2011 and 2014 proved that the measurable elements of learning activities show such time-dependent characteristics that correlate with visual communication forms and deadlines defined by study programs. From these results we may conclude that the methods and techniques to promote the interest of students in the curricula and the relevant development of learning activities are worth examining. In other words, it is worth studying how to utilize the potential in network learning, as such potentials are already perceived today, in the optimization of organic learning as demanded by individual learners and institutions.

Schools as organizations and teachers as key participants in the education process are in a difficult position. The 2.0 education paradigm targets the Net Generation. Those young people for whom knowing and using the internet is an organic part of life while the majority of schools and teachers organize teaching and education in a 20th century fashion. Typically, educational institutions still try to hide behind the walls of conservatism, while others respond spontaneously and often fight a unique battle to be able to successfully operate under the new conditions [1] [2].

Our hypothesis may be summarized as visual learning may provide opportunities to use parables that are able to improve the efficiency of human learning, currently based on traditional verbal communication and as such hindered by time constraints and information pressure. Developing curricula presented challenges in the fields of digitizing, multimedia editing and on-line publishing. Meta-data structure, SCORM conversion (converting contents into SCORM format with interactive elements) and formats matching the relevant criteria were defined as required by e-learning.

Our analyses proved that the measurable elements of learning activities show such time-dependent characteristics that correlate with visual communication forms and deadlines defined by study programs. From these results we may conclude that the methods and techniques to promote the interest of students in the curricula and the relevant development of learning activities are worth examining. In other words, it is worth studying how to utilize the potential in network learning, as such potentials are already perceived today, in the optimalisation of organic learning as demanded by individual learners and institutions.

3. Experiences regarding the Development Process

We were interested in the issue of use and access of the digital learning materials developed, so a survey was carried out in order to measure satisfaction and support our thesis.

In autumn 2013, among 15 students using the new curriculum, a representative satisfaction survey was carried using a digital micro-environment, after the first semester of curriculum’s introduction. The questionnaire was edited by Moodle (Modular Object Oriented Electric Learning Environment) system tools and the students were asked to send in responses using this system as well [5] [11]; see Figure 1.

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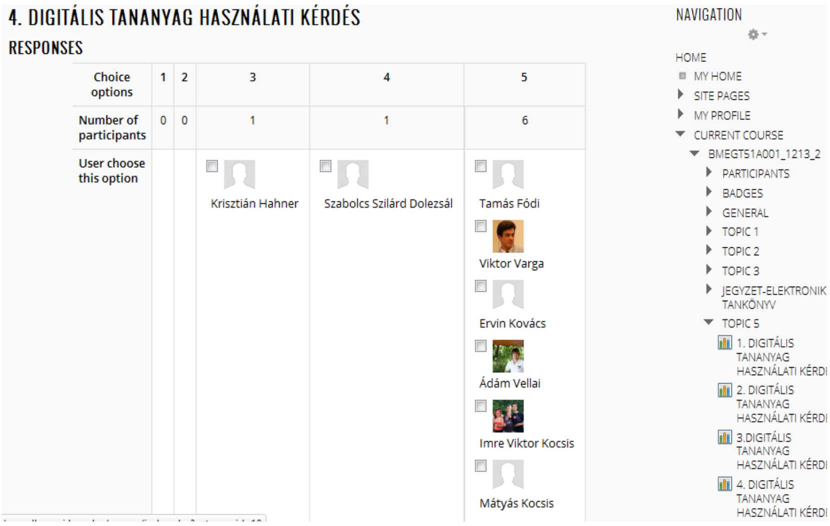

Figure 2. Student replies in Moodle System

The survey aimed at examining the using efficiency of curriculum presented in new visual form. The survey results are shown below. About 70% of the respondents are fully or greatly satisfied with the use and professional accuracy of new developed curricula; see Figure 3.

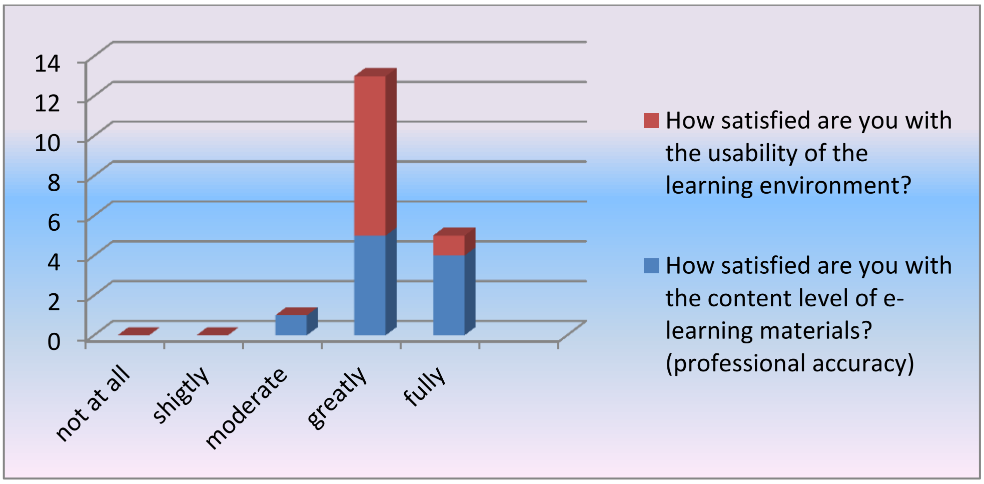

Figure 3. SCORM curriculum in Moodle System

The vast majority of responding students engaged with the curriculum 1-2 hours per day; see Figure 4.

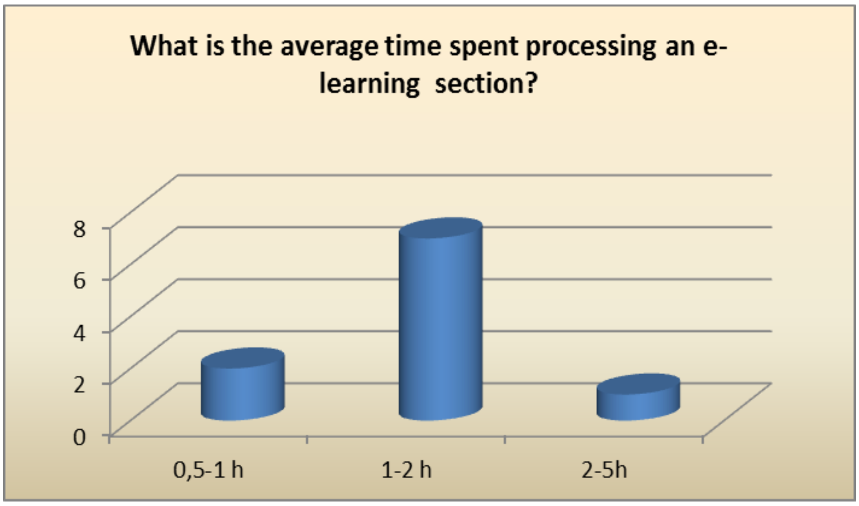

Figure 4. Student responses in Moodle System

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Overall, based on the response of the students we found that they are responsive to a new type of digital teaching materials, which the same time motivates them. It is due to the functional design of media objects in teaching materials used.

Another pedagogical survey took place between 2014 November and December. Target group was formed from corresponding students who took part in teacher training. Most (90%) of them are already working as teachers in vocational secondary schools. The aim of the survey was to measure the attitudes and level of use of digital culture among those who are familiar with digital curriculum. Many Hungarian researchers have already examined the typical characteristics of this target group regarding the career development, career tracking, or values assigned when entering labour market [4] [10]. To get the results, we used an online, cloud-based survey form. Both text and diagram-based qualitative methods were applied for processing the results. The study was representative, because on the one hand sample was taken from two biggest faculties of BME, and on the other hand every generation and sex was represented. For 21 questions 68 complete responses arrived.

The number of mailing lists use by students vary from 1 to 11. This number tends to be rather high if we take into consideration that we are talking about adult students. The social networking sites regularly used (beside Facebook) include:

- Google+
- Youtube
- Instagram, pinterest
- Skype
- TWOO, MyVIP, MSN,
- Moodle
- LinkedIn
- GoogleDrive

75% of surveyed have a Facebook profile and are active members of 3-4 Facebook groups.

In the case of ICT usage, 69%-a respondents have a smartphone, and the functions used on smartphones and tablets. Emailing is the most common and typical activity (52%), the second most popular is the search for information online (51%). And lastly, the third most common ICT activity is connected to usage of online curriculum (see figure 5).

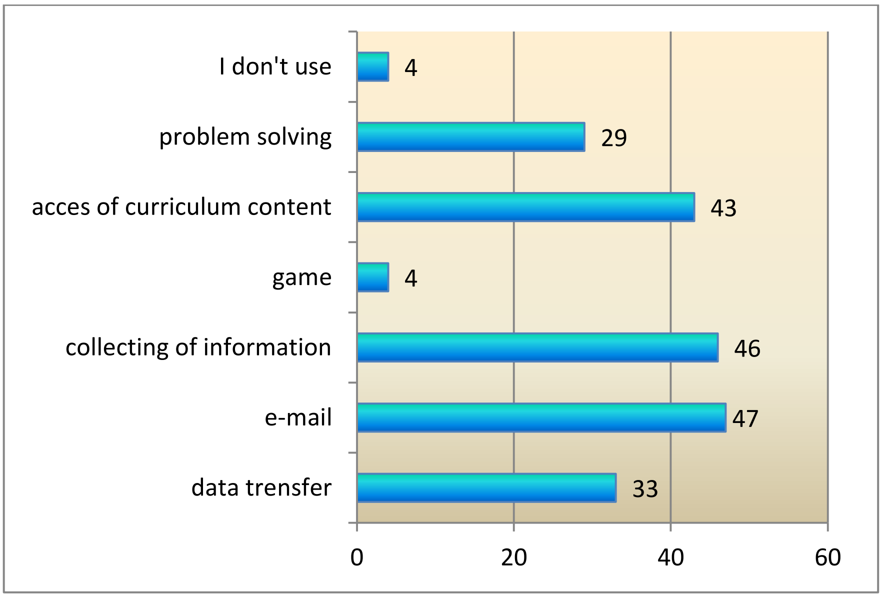

Figure 5. Functions used on smartphones and tablets

All the developed digital learning material is freely available for anyone to access on http://www.tankonyvtar.hu website (see Figure 6.)

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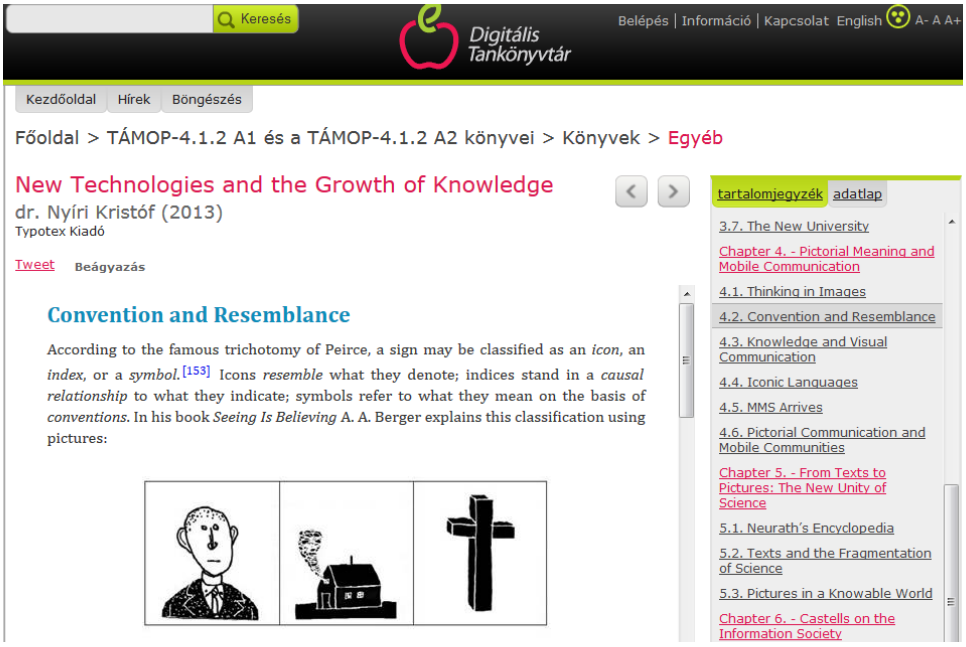

Figure 6. Developed digital learning material on open website

4. Conclusions

As a result of our research it can be stated, that nowadays in process of digital learning and communication no longer a specific application or program is the most important, then function itself. Numerous digital, internet-based services do not appear yet with the total instrument system, then just with their basic functions, without unconditional pragmatic rules. In our culture of methodology beside the traditional elements digital, up-to-date methods are more and more dominant [12].

Digital presence requires reliable technical and technological background, as well as the management of the real time processes. Not all digital citizens are prepared for this. The maximum of parallel processes run by users is 2-3. We also have to consider the fact that there is no canonized, unified connectivist e-learning system of rules. At the same time it is satisfying to see the openness from the part of the participants of the study to involve communication devices. More than half of respondents are willing to use actively mobile communication devices during their teaching activities.

While preparing of advanced digital curricula, we had to keep in mind a number of methodological and didactic aspects. These restricted the development directions. Such criteria were as follows:

- The developed curricula should be user-friendly, with easy usability
- The content on the screen should be responsive and adaptive to various frames and resolutions
- The structure of curricula has to be simple and multi leveled. At least three levels are recommended: modul-lecture-sublecture
- It is important to provide a constant possibility feedback in form of tests that can be taken independently by students
- Feedback solutions are supported by a number of other methodological possibilities for example a series of tasks to be sent
- It is also necessary to track student progress in a form of continuously monitoring their activity
- In addition, curricula should be easy follows with a low number of steps, and each curriculum should have a short extract content that is freely available

The SCORM-based form of learning materials allows the use of educational materials in the broadest sense. They can be handled and extracted into an html or xml structure. Our research shows that most of the target group prefers to access the digital curricula via mobile communication devices. Generally it means that it is their wish to gain knowledge while using their smartphones and tables. The digital learning materials should be developed with appropriate attention to these needs. This is to ensure the widest opportunity for digital citizens in the field of learning support.

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Advancement in educational collaboration – web hybrid applications in cloud based blended learning

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Abstract

New and emerging web application and services are offering many new exciting possibilities for education in distant and blended learning modes. On other hand universities and other educational institutions often develop their educational activities around several basic e-learning tools contained in Learning Management Systems (LMS). Learning Management Systems are standardized information systems for management of courses, e-learning content, users and tools. Although rich with tools and different add-ons they still don't allow users and administrators to fully integrate LMS content and functionalities with third party systems. Current architecture of most used LMS only partly support integration with different tools for authoring, sharing, decomposition, reuse, querying, publishing and other similar applications.
This paper explores e-learning possibilities offered by cloud based web hybrid applications in e-learning environment and offers proposal for future cloud based hybrid system.

Keywords: *e-learning in cloud, cloud learning management systems, informal learning*

1. Introduction

Fast development of information technology has significantly changed ways in which we perceive, learn, adapt, change and share information and knowledge in general. Not only lifelong learning as special paradigm, but learning itself is rapidly changing to adapt to growth of amount and ubiquity of information [1]. E-learning no longer signifies just usage of E-learning tools but importance of online learning across all modes of instruction, whether they take place in higher education, school-based or informal education [2].
Web itself became huge pool of diverse information and it's necessary to provide a mechanisms of storing, reusing and sharing critical knowledge with interoperability across number of different tools and services users are accustomed to use [3].
There is also ever-growing importance for sharing knowledge as fast as possible, dynamically and across different domains and contexts. That's why semantic tools based on proper ontology are needed in order to bring structure and automated or semi-automated metadata description of resources used so they can be indexed and accessed by different services.
Closed information systems with non-adaptable data models are hindering such user autonomy in managing different sources of information. They are also incapable of effective implementation of sharing, reusing and querying. Therefore internal semantic tools of such systems are usually week because they are oriented on single domain or specific types of content as well as specific ways in which they usually published.

2. Drivers of LMS development

LMS are powerful web applications designed for administration, documentation, tracking, reporting and delivery of e-learning education courses or training programs [4].Their development in past times were tightly connected with content they were serving and that is how they initially developed.

First LMS was originally designed for CD-ROM/LAN (local file-based) operations and web-based Javascript API (Application Programming Interface) runtime interface introduced latter was based on SCORM (Sharable Content Object Reference Model) standard [5].

In the beginning LMS were serving applications for specialized types of content. Each new version frequently required new version of software (new LMS) and for each computer platform new version of LMS was needed. That fundamental flaw of LMS are still partly present in modern LMS architecture since LMS are frequently focused on delivery of functionalities that would effectively work usually only upon internally handled content.

This historic introduction is significant because it shows what forced early LMS to come from limited computer platform environment into Web. It was need to present, edit and publish educational content without much of concerns for different interoperability problems. Current LMS platforms are built with different architectural perspective and various data formats and services. Therefore internal data procedures could not be easily made interoperable with other systems, nor are systems functionalities of LMS are easily exposable to third party systems [6]. For such reason all shortcomings stated previously can unfortunately be applied on majority of LMS that are in use today.

3. Blended, informal and formal learning in cloud environment

If we take into consideration that E-learning is the utilization of network technology to attain the function of passing on knowledge at anytime and anywhere [7] than we can hardy say that current LM systems are fulfilling duty. Besides, education is not only about content, as the trends in online pedagogy models make explicit that connectivism and social constructionism are playing most important role in high quality education today [8].

Such learning requires user to be connected with many different systems and other users, fetch data from many sources while dynamically creating content and communicating with different types of users (teachers, other students) from different learning systems and other knowledge based platforms.
Current LMS are not built on platforms that allow easy change of individual services and tools without major modifications of the system. For example teachers still heavily relay on old methods of sharing content like uploading files in LMS internal storage, and in case some changes are required than files are downloaded, changed and uploaded again. So even some version of cloud based content workflow (which should be default way of handling content by now) is not adopted as standard. In similar way students contributions grading can occur only inside LMS environment and partial or custom set grading for different informal activities are not easy to set or are not present at all.

Course structure is set in advanced in all modern LM systems and there is no easy way to use different layout designs by adding different services or LMS tools in customized fashion. Standardized look and feel of LMS have caused many users to stick with usual routines while creating content. Different web mashups can be added only from few standardized content providers and teacher have no options to add and customize their own content providers. Notifications and reporting from LMS environment cannot be easily integrated in third party systems. Course API is usually available but semi functional and support for them is limited and very rarely used at all except for communication of student and course data with SIS.

Ability to tracking student’s activities outside LMS is almost not utilized at all. Authors in [12] demonstrates how teacher have need to transform online resources into widgets. Evaluations indicate that this solution empowers the average teachers to become a widget author, without any programming knowledge. But it’s essential not only to have built in resources but interactive units inside their courses with options to grade users participation on different rich internet application, online portal or web application.

Learning is frequently not happening inside LMS simply because LMS cannot handle constant update and amount or relevant data and activities that are present on different web resources which are constantly updated. We’ll have to conclude that is not possible for standard LMS to index, track and interact with all resources that learners are interacting in order to provide quality environment for monitoring, grading and enabling learning activities across web.

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3.1. Cloud platforms assisted blended learning

Cloud technologies become attractive e-leaning technology due to its dynamic scalability and effective usage of the resources [9]. Authors in [10] defined current LMS architecture and proposed complete migration to Cloud computing platform with explanation of all benefits that could derive from such architecture. Authors in [11] are going above that explaining problematic that needs to be addressed in current environment before proceeding, mainly: technology upgrading and change, interoperability, centralization and access beyond institution. There is also importance of organizing formal and non-formal learning and students PLE (Personal Learning Network) with competence catalogue which would facilitate sematic description of informal learning experiences [11].

Semantics is always challenge if we seek to value informal learning activities. Therefore merging of semantic technologies with cloud computing is in the eye of the hurricane of new web developments [12]. There is no long term efficiency and proper integration, tracking or any other functionality for that matter without proper implementation of ontology and semantics in modern web applications. Trailer system describer by authors in [13] addresses similar issues. There has been other attempts to value informal and formal learning on the web ([5], [6]) and understand impact of cloud environment on learning processes and how to apply proper pedagogy procedures in that case; but we haven't seen effective acceptance of such tools in e-learning environments.

4. Challenges for successful LMS-cloud integration

Many valuable proposals tried to leverage and propose effectiveness of successful integration of learning activities in cloud environment. Main challenges in the way would be:

- Successful integration with existing learning and other existing supporting information systems.

We have seen proposed architectures that are giving complete road map on how to migrate existing services into cloud environment but transition in reality cannot easily follow that pattern. There are many legacy systems (not only LMS) that needs to be taken into consideration. SIS (Student Information System) is starting point of integration - allowing authorization and data acquisition from cloud applications as well as better integration with LMS.

- Supportive cloud environment with adept tools for educational purposes of different types.

We have seen different Microsoft, Google and other cloud services being launched with "education" emphasis but those cloud services cannot be easily integrated in educational services in different learning environment. They usually provide good foundation for creation of new generation of educational cloud services because they provide stable storage with powerful collaboration features, event management features, email integration on institution level and similar. What is missing are instructions, case scenarios, tools, additional API and examples on how to build and integrate cloud applications in cloud in combination with different types of existing standardized infrastructures, LMS and SIS systems.

- Advanced adaptive schemas for semantics and ontology.

Different services on the web use different ways of naming different types of data for internal handling and also for communications with other systems. Some are standardized according to SCORM [2] but in many cases situation is still quite challenging since there is not standardized procedure for all activities [14] in informal learning on the web so there is going to be problems while communicating with any standardized LMS. Obviously there should be standardized procedures, data types and API's defined with agreements between key institutions on how to implement them but we still have to wait until that happens. Meanwhile we need to find way to assess and track learners' progress on the web wherever it is happening as part of informal or formal learning. There has been good attempts recently to assess those activities ([1]) but we are far away from standardized procedures.

- Tracking, assessment and collaboration.

We need to be able to preserve learners' privacy and still track activities across web with customizable tools for measuring quantity and quality of our learners' contributions across wide variety of tools and services on the web. But measurements are not enough in this situation since we also need ways to link them with rubrics and assessments in LMS that will allow us to give students real time feedback. Gamification tools that recently emerged in LMS tools are promising but much needs to be done so we could effectively integrate them with third party tools.

5. Hybrid LMS - Cloud e-learning applications

As a starting point of our proposal we will take established procedures in cloud architecture and propose advancements in order to resolve previously defined problems.

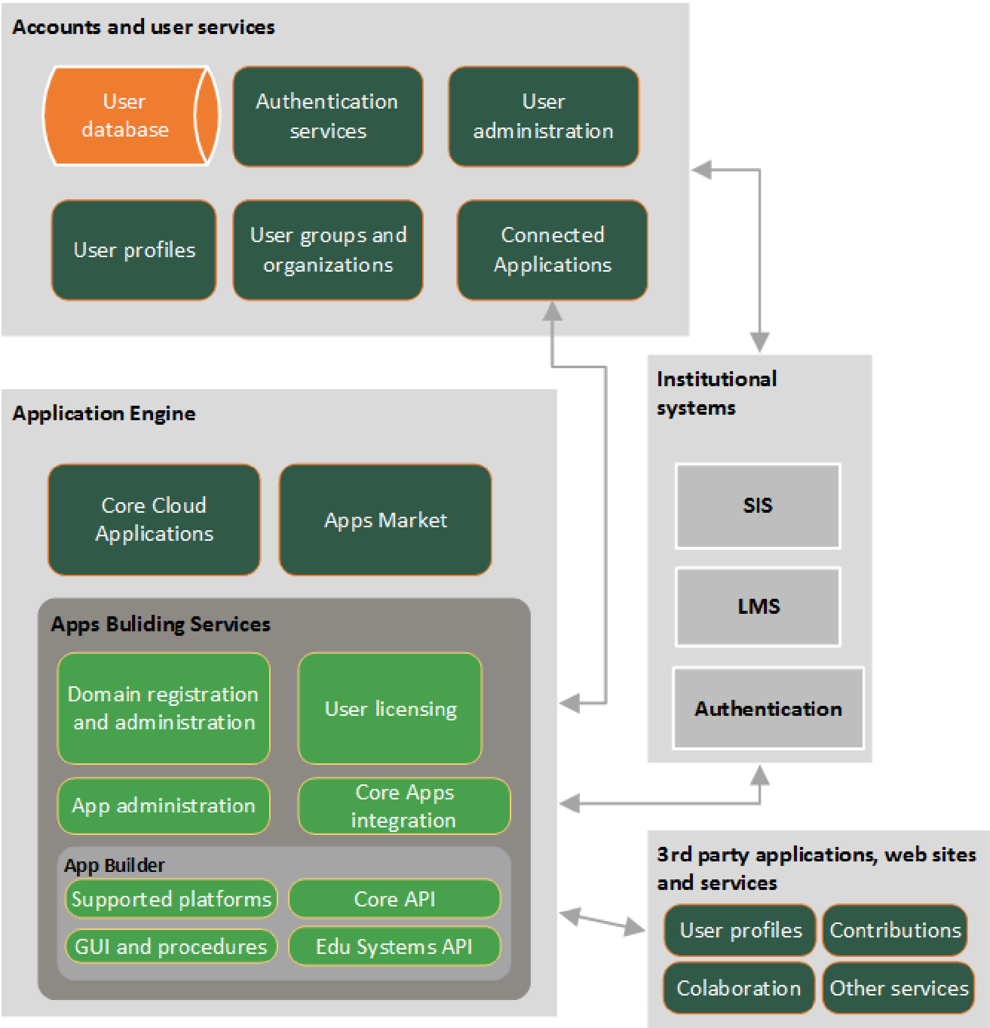

Figure 1. Cloud App Engine

Figure 1. defines core services in cloud infrastructure with “Accounts and users service” for management of user accounts and “Apps Engine” for management of cloud applications. User account management is usually used to synchronized user accounts, roles and privileges between services like SIS, “Accounts and user services” and LMS. “Core Cloud Applications” represent set of standardized cloud applications for storage and editing standard types of documents (docs, sheets, slides, pdf, txt) usually more applications could be added (paid or free) by administrator form some sort of Application Market.

Addition to that standardized setup is proposal of “App building service” and “App builder” that allows administrators to create applications using different frameworks (Perl, PHP, Java etc.) supported by cloud service. App engines like that already exists but in our proposal we’ll focus on support for scenarios where administrator from LMS wants to build cloud application specialized and customized for needs of specific educational institution with emphasis on integration of informal learning activities.

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Example of such apps would be application for monitoring user progress across key services on the web which would include monitoring page views, contributions, ratings and acceptance, user group projects and collaboration progress on third party services or web sites.

Purpose of such enhanced framework would be enabling of advanced features and incorporating them into existing learning environment. Examples of features are:

- enhanced application for collaboration

This would enable creation of customized web environments. Specialized collaboration apps could allow students collaboration while writing: essays, project, and scientific articles from online apps which would be integrated with enhanced learning content tools and references which will be explained latter.
Users would be able to collaborate on joint projects inside its own cloud environment or in collaboration with other educational institutions or on the recognized third party service with tracking of user contributions and marking progress and milestones.

- enhanced existing learning content tools and references

Bookmarked sites, custom library, annotation, commenting and highlighting tools, custom web scrapping, web objects and learning objects library, news alerts are all cloud tools that could be integrated with cloud core storage engine together with custom searcher which could help learners to search their storage, their colleges' resource and also schools library and scientific databases on which school bought access - all from single location.

- educational internal social network

Transparent monitoring would allow creation of social-like news feeds where students could see contributions of their project groups or class participants in internal or external learning apps. In case professor wants embed gamification experience it could assign points or badges for each type of students contributions progress.

Instead of just programmatically support various platforms, "App engine" should be focused on providing intelligent semantically enriched approach so less knowledgeable users would be able to create applications by using semantically enriched building blocks. Apps could harvest types of data records from knows services and then allow professors to build application which would allow monitoring of users activities with approval of service owners. **Error! Reference source not found.**. shows how whole process might look.

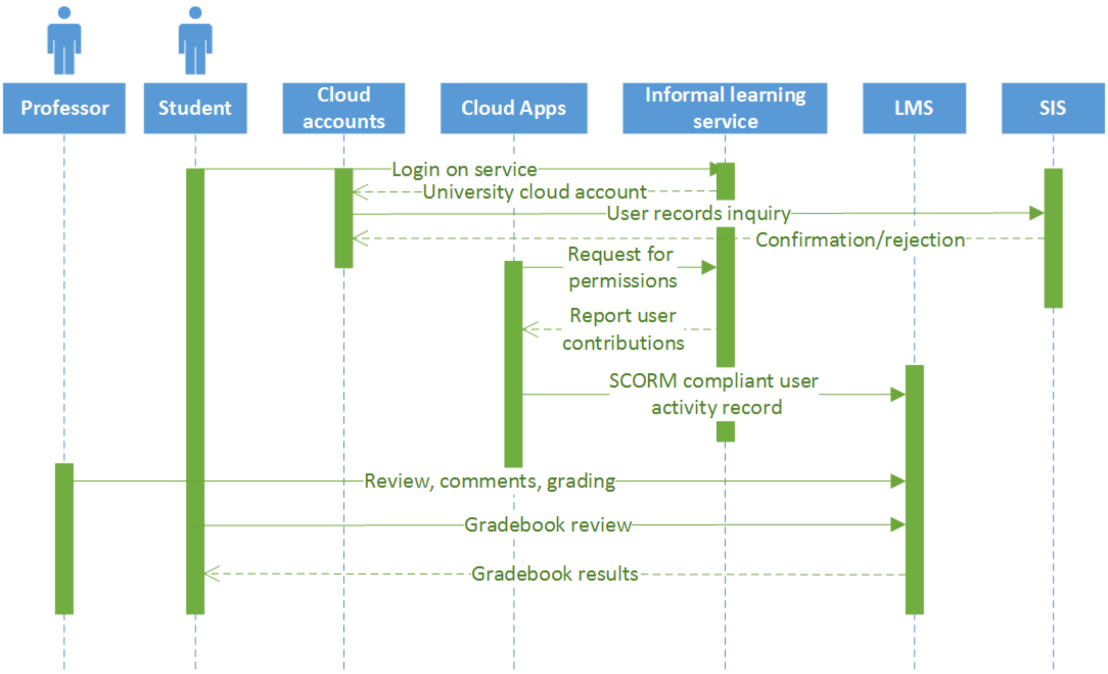

Figure 2. Integration of informal learning activity with cloud and schools' systems

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For example: Computer science students are learning about web server administration. Group have to set up their own web server and create comparison between few open source applications using open source performance testing tools. While they run into several problem professor is not giving them solution but directing them to post question on Stack Exchange portal [7]. They start using schools account in order to use Stack Exchange service. User is logging on service with schools account which is checked with SIS. After that Cloud Apps application for monitoring users' progress on Stack Exchange is launched. User progress and contributions is logged and monitored by application. No special application permissions are required since application only needs to harvest data which is already available on the web site of the service.

Effectiveness of such gamification approach applied on portals like Stack Exchange is explored by several researchers ([15], [16], [7], [8]) with options to leverage possibilities for integrating high quality content by using Big Data services in education ([17]). Similar approaches are proposed by authors in [18] where they explain how Wiki-Learnia (social platform for lifelong learning) works.
Authors in [19] on other hand are showing how future e-learning adaptations, like the ones' we are proposing, could benefit from SOA (Service Oriented Architecture) while building necessary e-learning platform.
Stack Exchange is not only example – distinguished authors have similar opinion about other popular platforms. For example number one way of getting a job in any programming company right now is to have a GitHub account and show your work ([20], [21]). Obvious step for incorporating e-learning for programming students would be to measure their success and activities on GitHub for example. Or in other words to find a ways incorporate informal learning into formal and to find ways to measure and assess other forms of informal learning. But not only that, that kind of approach enables PBL (Problem Based Learning) which is becoming popular approach especially with MOOC (Massive Open Online Course) where we can see effective merging between industry needs and education ([22], [23], [24], [25]).

6. Conclusion – towards future browser based Learning Management System

Future of architecture explained in [20] would allow user to put browser in "learning mode" (LM). Just like users signed in certain cloud environment have access to different cloud applications in same way users in LM mode would be able to access resources and applications added in LM students' profile by their institutions.

LM would transform user browser by using browser and cloud application in cloud based LMS itself composed of customizable chunks of activities and resources. Therefore we would achieve dismantling of centralized learning present today with current LMS and disperse it into LMS applications functioning inside user web browser.

Browser LM mode would allow users access to thousand learning resources through browser applications that could function like custom made expandable mash-ups (widgets or tiles) inside user browser window with social learning feed in the centre of user attention. Contributions would be monitored across different user activities: reading online resources, commenting on them, viewing video materials on different portals, using online or mobile apps, discussing on different topics on relevant portals, taking self-tests, quizzes or even monitoring attempt on real certification exam in case student has desire to excel in some field.

Ease of setting up adding and monitoring new resources could allow not only professors but also students to add any new resource inside LM while they are learning on the web. Others would see resources added and would have option to add it to their learning environment and if professor likes that resource could become part of default or optional LM setup.

Continued migration of e-learning activities in cloud environment would allow creation of learning environment like describer here. Migration from traditional platforms is happening slowly but biggest problems would not be migration in cloud itself, which is already under way, but effectiveness of integrations of informal learning activities in cloud environment. Cloud environment could offer many

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advantages but if used with inflexible traditional mind-set it will only be recreation of linear activities taken from LMS in cloud which will not significantly enrich current learning approaches. We have to truly grasp idea that learning did become ubiquitous and then we'll be able to support it effectively.

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Addressing Learners Challenges in Open and Distance Education with the Focus of Literacy and use of ICT Tools, Case Study Focused on the Open University of Tanzania

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Abstract

Information and Communication Technology (ICT) is playing a fundamental role in open and distance learning (ODL) to meet the necessities and opportunity of the learners' in large scale.
The challenges, which faces the students who are enrolled in university with ODL system is ICT literacy at large. ICT is a tool, which is used to help learners to attain their goals, and has been the major factor for providing high quality of education in universities. It is difficult to carry out the same using any usual institutional scheme due to its partial resources. ICT has various proven tools and technologies to meet the requirements of a learner in different skills. The question is; do the students know how to access the contents in online system instead of using other form of study materials?. This paper analyses what are the challenges that learners are facing and ways that will be able to solve the problem of ICT tools literacy. In addition, ways on encouraging the learners on the use of ICT tools to improve the quality education

Keywords: *Open distance learning, ICT, learners*

1. Introduction

This paper is written based on the perceptions, notion and experiences learner as student at the Open University of Tanzania (OUT), had on their knowledge of Information and Communication Technology, case study in Open University of Tanzania in the Regional centres which have learners who sided in urban and mostly in rural areas

ICT has been transforming the way we communicate, the way we do business, the way we work – it is inevitable that it changes the way we learn and the way we teach.
Information and Communication Technology (ICT) is playing a fundamental role in open and distance learning (ODL) to meet the necessities and opportunity of the learners' in large scale. As a definition of ICT a term "diverse set of technological tools and resources used to communicate, and to create, disseminate, store, and manage information" which includes devices such as television, radio, mobile phones, computer with its network components, satellite systems. These devices that will help in different applications such as videoconferencing, education, health etc.
Information and Communication Technology (ICT) is made up of three terms, namely,
Information, Communication and Technology.

- **Information:** this data have been processed analyzed, interpreted and meaningful to the receiver of a massage. It is needed for problem solving and decision-making. Message is an essential element in information and should therefore be “accurate, concise and of superior value”
- **Communication:** This is the process of transferring information from one source to destination or from one person to others or group of persons (listeners). Information is thus related to communication.
- **Technology:** It is the process of using information to have meaningful control over nature in order to survive the challenges and changes in our environment so that a civilized life of higher standard of living can be achieved.

1.1. ICT in education

In recent years, there has been a upsurge of interest in how computers and the Internet can best be harnessed to improve the efficiency and effectiveness of education at all levels and in both formal and non-formal settings. But ICTs are more than just these technologies; older technologies such as the Telephone, radio and television, although now given less attention, have a longer and richer history as instructional tool Example, radio and television have for over fifty years been used for open and distance learning, although print remains the cheapest, most accessible and therefore most dominant delivery mechanism in developing countries.

1.2. Open and Distance learning

Majority of people believes that the distance learning is a learning through post office and it is available to older people who wants to go for furthers studies in order to be promoted in their work place.
By definition, ODL is learning through which learners can be free from all constrains of time and place which offered flexible learning opportunities. Also defined as a field of education that focuses on the andragogy, technology, and instructional systems design that is effectively incorporated in delivering education to learners who are not physically "on delivery site" to receive their education (*Kyando N, 2011 OUT)*
ODL is offered in variety of print and electronic format either through synchronous communication or through e-learning , audio visual and the internet. Thus in Open University of Tanzania though ODL there Examination on demand (ODEX) which also is offered through ODL system. ODEX is concept attending examination flexibility to the open and distance learning. This will make the total system of examination independent of the period and will help the student to take up the examinations as per their wish and preparation of intended courses.

The fast pacing ICT developments have not spared Open and Distance Learning (ODL) evolution in Tanzania. Its influence over broadcast technology, seem to provide a much wider room a more or less automatic transformation from one way to two ways synchronous telelearning systems (.i.e. audio and video conferencing)

1.3. Problem facing ICT in ODL

As Open University of Tanzania move forward in implementing the use of ICT tools as one way of presenting the material contents through e- learning. But, what about our learners? Do they know how to go with these changes? Do they need to change from paper-based to electronic format through ICT tools? The problem is that some of learners are from the rural areas and there is shortage of power or no power source at all. It is difficult for them to go through with these changes. Also, there is problem of awareness of changes. Most of the students do not use computers and mobile phones for studies and instead they use study manual, which they have been given. In addition, some of them do not have literacy of ICT tools especially computers in order to use it for their studies through e-learning management system.

1.4. Area of study

The study done in the regional centres where by the university have its centres there and mostly purposely was to show the relation between rural areas and urban areas. In the rural areas it was difficult to see how the ICT being used and in the urban small percentage of learners were using ICT tools for educational purposes.

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1.5. Results of studies

Learners who interviewed before writing this paper were from two regional centres the result are shown below in the bar chart which shows the variation of the learners who were interviewed in regards to ICT literacy.

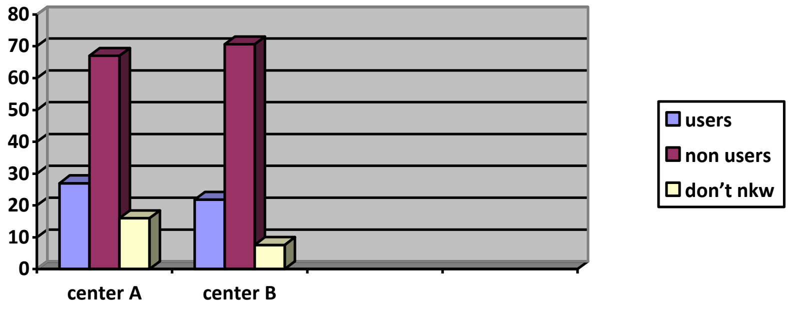

Figure 1. Bar chart showing the variation of ICT literacy

How literacy can be shown
The literacy can be shown on how learners can be able to have an access ICT tools in their daily studies and it can be shown on how many percentages of learners can use ICT tools like mobile phones computers and others

1.6. The ICT tools used in open and distance learning

Students of open and distance learning can learn anywhere and anytime across the globe through the use of ICT tools which include computers, mobile phones, television but will explain in detail on computers and mobile phones on accessing the web-based information which is available in moodle contents.

1.6.1. Computers

This is an electronic device that is capable of receiving, storing, manipulating and retrieving data speedily and efficiently. Computers can help learners to assess online material that are uploaded by lectures in the moodle. The availability of the hardware and soft-The availability of the hardware's and softwares helps the learner to choose institutional materials that meet his/her needs. The computer is an educational technology medium for individualizing instruction. Therefore, renders excellence service in ODL both as a tutor and as tools helps the learner to choose institutional materials that meet his/her needs. The computer is an educational technology medium for individualizing instruction. Therefore, render excellence service in ODL both as a tutor and as a tool. However, are the learner knows how to access the contents? Most of the learners do not know if there are online contents instead of paper- based contents. Computers also can be used to help learners to have **study after- accession-** they can use to save material that is being downloaded to the moodle
Also in order to have access to web information the learners should have modems which will help them, there modem are somehow expensive but there are some operators who are cheaper and faster than others

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Figure 2. Students in computer Lab

1.6.2. Mobile phones

The quality of the learning experience provided by mobile technologies is of vital importance and student views should form a key element of any evaluation. Mobile education can be defined as learning opportunities that are offered through mobile devices such as mobile phones, MP3 and MP4 players such as iPods as well as personal tablet devices such as iPads. Some of mobile are embedded with web- based application, which will help learners to access information and to communicate in discussion forums due to the distance between them. Mobile also can be used in such a way that it can be dictionary and to access the internet to find some of topics, which are being difficultly explained in the paper based. However, do learners know how to use mobile phone as tool of education and not as a tool of daily communication?

Figure 3: Web based mobile phone

There are many ICT tools that will help learners like networking devices television, audio and video devices that needs to be explained in terms of literacy.

1.7. Problems facing learners in ICT literacy

Enough Power Supply: Almost all ICT require steady supply of electricity to function. However, unfortunately, electricity supply in the country is epileptic and many rural areas are yet to have electricity. This creates serious problems in the promoting ICT literacy open and distance-learning programme

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Steady Internet Connectivity: Observation has shown that there is low internet connectivity in rural areas in Tanzania. To make learners Information and Communication Technology especially computer literate. ICT project should be made a priority by government enable learners attain the educational level needed. This is big problem to the learners in accessing online contents.

Small number of Telephones user: This is the problem facing ICT literacy in open and distance learning. Access to the use of ICT tools such as telephone with IP that have internet connection and cheaper and internet connectivity has been very slow especially in rural areas. With the increasingly use of GSM mobile phone the use of ICT resources (broadband telephones) for educational purposes in general and open and distance learning in particular has been decreasing.

Lack of enough Income: Many Tanzanian still lives below 1Usd per day. The cost of computers and other ICT resources are far beyond their reach, which led to low level of computer literacy in among of learners. This is the major fact for underdevelopment of ICT literacy in Tanzania.

Socio-economical believes in the society: Some people believes that to have an ICT literacy someone should have a lot of money also believes that there is no need to know these tools because others will do for them. In addition, some of learners believe that because they are provided with paper based study material there is no deed for ICT tools to study.

Location factor: There are other parts of Tanzania especially in rural areas it is difficult to attain ICT literacy because of its locality. In rural areas most of ICT tools are not available at all and if are available but will be with lower quality and don't support internet services.

1.8. What should be done?

There are many solutions to every problem. First in the case of learners there should be way that, there is a need to encourage learners to build awareness to themselves and the importance of literacy of ICT in their daily activities especially studies

Secondly, there is a need to advice host institution to develop platform for mobile users network system to alert learners on what is going on and to be able to access to the moodle with their mobile phones.

There are face to face sessions in every start of the academic year, there should be the way in which the institution should conduct training on ICT and help learners to be able to use all ICT tools and to provide with affordable computers and mobile phone for their studies

In case of shortage of power especially in rural areas where there is shortage, learners should be advised to have other source power which is cheaper like affordable solar energy and wind energy for charging their ICT tools.

Lastly, in the case of internet connections, convenience of a service shall be ensured only with the availability of internet bandwidth, as it is one of the key parameters. As allocation of internet bandwidth to a specific service is directly proportional to the amount of usage of that service, there is a need of dynamically allocation of bandwidth with lower cost. there are other internet providers and mobile companies in Tanzania that provide internet with cheapest bundle per month and it is affordable to all, and learners will be able to afford that.

1.9. Conclusion

ICT is playing a vital role in open distance learning in Tanzania. As ICT, literacy is very low to *most* of the learners. There should be a need to create awareness on the importance of all the tools. The initiation and affordability of new technologies, such as portable devices and wireless networking can be exploited to further widen the access that learners in the university. As there is a saying that charity starts at home, but here ICT literacy should start a in level of primary schools so that to enable learners in ODL Universities to use them easier

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Globalization and Cooperation in Engineering Education

ICEE 2015

Quality matters in projects with Turku University of Applied Sciences

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Abstract

Nowadays it is quite normal to teach students with projects from a real work life. Both sides win, students will learn how to handle real life projects, and vice versa, companies will get quite cheap work labor with the newest knowledge on IT and enthusiasm. Engineering students in Turku University of Applied Sciences have practiced many years this kind of learning in engineering education. However some problems do exist, which have to be taken into consideration. In many cases it can be hard to get suitable projects from the industry at the right time. And as well as this , when companies have suitable projects there is no time for students to take part in these projects, because they are rushed to complete their theoretical studies. In this paper typical quality problems between companies and Universities of Applied Sciences are discussed and some conclusions are drawn and practical innovations are suggested.

Keywords: *Quality, Co-operation, Project.*

1. Introduction

In Turku University of Applied Sciences (TUAS) [1] there was a need for a change in teaching. It was found old fashioned to teach in a classroom with the teacher speaking in front of the class and with the students just passively listening. Of course laboratory work between the lessons enables students to practice learned matters "hands on" in the Universities quite modern laboratories. Despite this modern environment at school, the feedback from industry was very demanding; the recently graduated students lack the knowledge and understanding about rules of working life. Also matters in this industry change so rapidly nowadays, so the knowledge of young engineers can become outdated quickly, especially when they first come to the work market place.

On the basis of this industry demand we have tried to build many ways to answer to the incoming needs. E.g. we have built projects together with companies, where students are involved. The titles of these projects come in many cases from industry. The students are enrolled in co-operated projects working with both our school but at the same time in the companies as well. Recently we have built together with the city of Turku and industrial companies a technology centre called "Machine Technology Centre Turku Ltd"[2], where students can make real projects with industrial companies and students from vocational school.

These new kind of teaching methods are also quite demanding for the University; the level of teaching quality must remain, or even improve. The many types of challenges of this kind of teaching, which we have met in TUAS are discussed in this paper.

2. Description of typical co-operation

Co-operation in this paper is considered as many kinds of activities, which are done together with TUAS staff, students and industrial companies. The assumption is that, the co-operation is affordable to each partner.

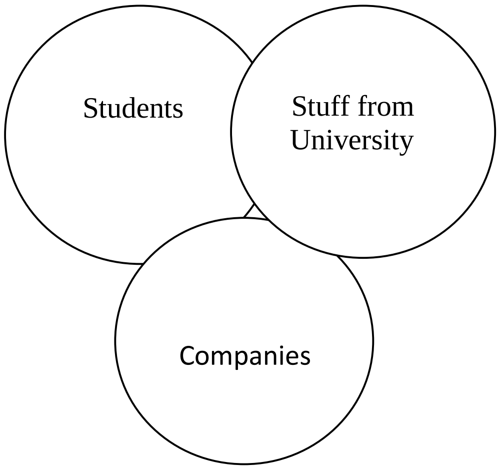

Figure 1. Co-operation, TUAS and companies

As shown in figure 1., successful co-operation needs students, stuff from the University of Applied Sciences and of course companies, which want to co-operate with the University. Together we can make thesis works, service work, many kinds of projects and R&D work.

2.1 Service Work

The first steps in this co-operation method were made over 15 years ago. Discussions with industry in our advisory board led to some ways to serve industry using the equipment from our laboratories. Some measurements, e.g. noise level, humidity, EMC, etc. were done together with laboratory engineers from school and some active students. 3D modelling and research service for combustion engines were started in very early stage. The purpose of this kind of co-operation was to develop new contacts for companies. It was found useful to our teachers and also students. We still carryout service work for companies, although project work is increased significantly.

2.2 Research and Development Projects

Nowadays the research and development activities are the most powerful increased learning environment for our students. This learning method combines learning, co-operation with industry and research. We believe that this kind of work increases students' capability to create innovations. Also it is very important to combine many types of students from different fields, e.g. business studies and engineering. This working method is a part of learning methodology, which we in TUAS call "Innovation Pedagogy" [3].

2.3 Other Ways of Co-Operation

There are of course many ways and combinations to co-operate with industry. In many cases, the projects which industry offers to school are quite small. E.g. a small project can be a product development work, where the whole class can be involved. The class can be divided in smaller groups, which try to develop the most innovative solution to the problem. The jury from the company evaluates the results and may reward the best group. Every student gets ECTS points and lot of experience from product development work.

One way of ensuring this co –operation is to give the possibility for the student to complete part of the studies in the company. Normally the student makes the thesis work and the compulsory practice in industry. The practice and the thesis work are written in the degree programme, so every student must include both these in their studies. In many cases an idea for the thesis work comes from the company, where the practice has been done, and if you are lucky, you can earn your first workplace there, too. The flexibility of the program means that it is also possible to modify your degree programme so that you can substitute some courses with a project from a company; for

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example, it is possible to substitute perhaps one year from your conventional studies with the projects and work life studies. This way of learning is quite demanding, for both students and the teachers. Also this way of learning needs a total commitment from both the University and the company, but the results can be very good.

3. SWOT Analysis of Co-Operation

It is important to think how this kind of co –operation really benefits the whole learning and teaching process. Ratio benefits versus disadvantage must be clearly favourable.

3.1 SWOT analysis of the co-operation

Mr. Jansson and Mr. Vaskikari have studied the effective co-operation between industry and university [4]. The result has been shone in SWOT (Strengths, Weaknesses, Opportunities, Threats) table:

Table 1.

Strengths • Excellent motivation of the students with real tasks • Possibility for versatile learning (technology, entrepreneurship, teamwork) • Students are usually a heterogeneous group which is creating ideas • Projects can be made “free of charge” for company, but in many cases the costs will be charged according the expenses • Thousands of Credits achieved with projects • Speed the thesis works • Teach real and right methods for students • Give new possibilities for Industry for innovation	**Weaknesses** • The group of students are changing and make not possible to have same persons for the whole project period in long projects • Start-up of the projects takes too long time for urgent cases
Opportunities • Integration of training courses and industry, courses will be developed and companies get manpower without financial expenses. • The operational model of the engineer workshop as a cooperative "enterprise" • Expansion to other fields of education (business students marketing the activities etc.) • Creating training opportunities for students. Our students have obligatory training period every summer between Spring and Autumn semesters. • To build versatile networks • Projects with industry, can be developing projects for industrial products, development projects for manufacturing methods, information evaluations including benchmarking. Projects which include all mentioned types with addition of prototype manufacturing the designed products usually include also testing and re-developing the products according the test results • Reduced costs for university	**Threats** • Maintaining the operational preconditions in a weakening economical setting (maintaining the equipment) • Establishing the position as a credible business partner • Have to keep the business simple enough, financial responsibilities can make harm

The conclusion of this study suggests that co-operation is valuable and vital now and in the future. Co-operation creates possibilities, develops the university´s organization and gives a great opportunity to industry for innovations. Financially, projects done with industry can save costs for the university when “classroom studies”

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have been brought to the real environment. Effective co-operation needs continuous organizing, scanning and benchmarking to be kept up-to-date.

4. Quality of co-operation

As shown in SWOT table, co-operation is considered very useful and worthwhile to do now and the future, but there are still a lot of opportunities to develop this model further. There may exist some weaknesses and threats, which have to be taken into account. These weaknesses and threats of the co-operation can be settled under the word quality, and use the Deming PDCA (Plan, Do, Check, Act) cycle [5] to analyse and continuously improve the quality of co –operation.

Figure 2: Deming: PDCA cycle

4.1 Things learned from co-operation

In TUAS we have noticed from the projects some important matters, which we must take into account, so you can improve your co-operation. Using the PDCA cycle, we try to learn from the mistakes which have been done in our co -operation, and innovate new ways to act. Using PDCA thinking you make continuous quality improving, which increases the level of teaching over time. Lately we have implemented the following notifications, which may be helpful in real projects:

- Get to really know companies you work with. It is very important to know the companies, the organization, people who are responsible in those areas, where you want to build up co-operation. You don't build relationship in one night, it may take time, months or maybe a year to do that. We have noticed that it is good to have not too large a group of companies, which is the core group, where to put the most effort for building relations. These are the companies, which really want to work with you and see the benefits, which can be obtained from the co –operation.

- Be realistic with the projects. It is easy to overestimate the capacity of the students for carrying out projects. Students normally have their own timetable for degree programme courses, so it can be difficult to fit project meetings into this as well. It must be clear to the company that the time schedule cannot be too tight for the project. Also, it is possible that some students can suddenly withdraw from the project. It can be a very stressful situation, when the workforce leaves the project, when there are the most critical phases going on. This can be avoided to keep a reserve bank of students, so you can substitute a student to another, when necessary.

- Select the right projects. You have to be experienced to select the relevant projects, which are not too difficult to handle and also, are not too long and complicated. This can be a difficult task, because if you want to get e.g. financial funding from the authorities, the projects must include some potential risks, have many participants, companies and universities, and knowledge level is very high. The risk of failure is very high in these projects. You can manage well this kind of projects, but they need experienced and an exceptionally good project manager.

- Select the right students for projects. It is very important, that you have active and innovative students in your team. It doesn't matter if they are unexperienced students, most important is that they are excited

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to learn new things. It is good to have active students from all levels of schools; those that have just started or more experienced students, from University, University of Applied Sciences and also from vocational school level. In this kind of team students can practice their roles, where their training is aiming them. University level students can perhaps carry out research work in the project, students from University of Applied Sciences can carry out some practical engineering work and act like a foreman in the team, and the student from vocational level can do for e.g. assembly work, programme a robot etc. We have done this kind of project a few times, where all levels of training were encompassed. Normally, in smaller projects, there are only a few levels of training in the team.

- Also the teacher, who implements projects of this nature should have basic experience from industrial work. It is much easier to find the common language, if you know the basic rules of the industrial company. E.g. in which business area the company is working, how it is situated in global business, which are the basic functions inside the company. An updated organization table is good to have, if possible. From it you can find a right contact person for your projects and purposes.

- The company should have a named contact person, who takes care of the project from the company's side. It has happened, that a company has suddenly had a big business project, so we lost the company project person to this project. This is a quite normal risk in smaller companies. Somehow you have ensure that there is a backup person who can lead the project to its end in this situation.

- Don't be responsible for everything, rather delegate as much as possible. It is good to give responsibility to the student members of the team. It is good to practice this, because nowadays the organizations in the companies are very thin, so the young engineers have to take responsibility in projects quite soon when they start working in the companies.

- Spread the results of the projects. When you have done a successful project, it is wise to promote this to other companies. Many teachers visit companies quite often, e.g. just discussing about future projects, for thesis works, etc., so it is good to mention then what you and your student team have done lately. It gives confidence to the company, especially if it is a new partner for you. A useful thing to do it to make a project report, which you can introduce to the company. In larger projects in TUAS, we make on official project report, which will be stored in our own database Publikaattori [6].

- Take care of financial things. Although there exits a favourable atmosphere in a company for common projects, everything can change rapidly if money is lacking. Some big product development projects in TUAS have been interrupted because of a lack of money. Also, in smaller cases, when you for e.g. have to buy components to a small project, you must be sure who pays the costs. Things concerning money should be written in the contract between the company and the University.

- Make co-operation happen all of the time. It is necessary to maintain contacts and relations with the companies and the core companies need to be liaised with quite often. Networking is the word of today. Reality is, that only few companies call you and suggest co - operation from their own interest. Nowadays companies are so busy so they don't have time for anything else but their everyday business. Also people in the company can change work, so you have to be aware of these personal matters, too.

5. An example of successful project

Fastems Ltd[7] ordered last year a fully functional pilot model of their FMS system from Machine Technology Centre Turku LTD. Involved in the project were many students from TUAS and Turku Vocational Institute (TAI) [8] (Picture 3) involved. The pilot model was totally financed by Fastems Ltd.

There was also one excellent thesis done from this project. This thesis discussed the design and implement of a controller board to control the station in the functional FMS scale model. Controller board function is operating as the interface between the logic controller and the scale model stations. The written parts of the thesis go through required properties of the controller board and what components were used. The controller board needs software to operate and these principles are also discussed. Software's are also discussed the communication and the available commands. As the result of the thesis, the FMS scale model gets suitable controller board. The controller board completes all requirements and communicates properly of the logic controller. This pilot is now travelling around the world and is shown in international fairs.

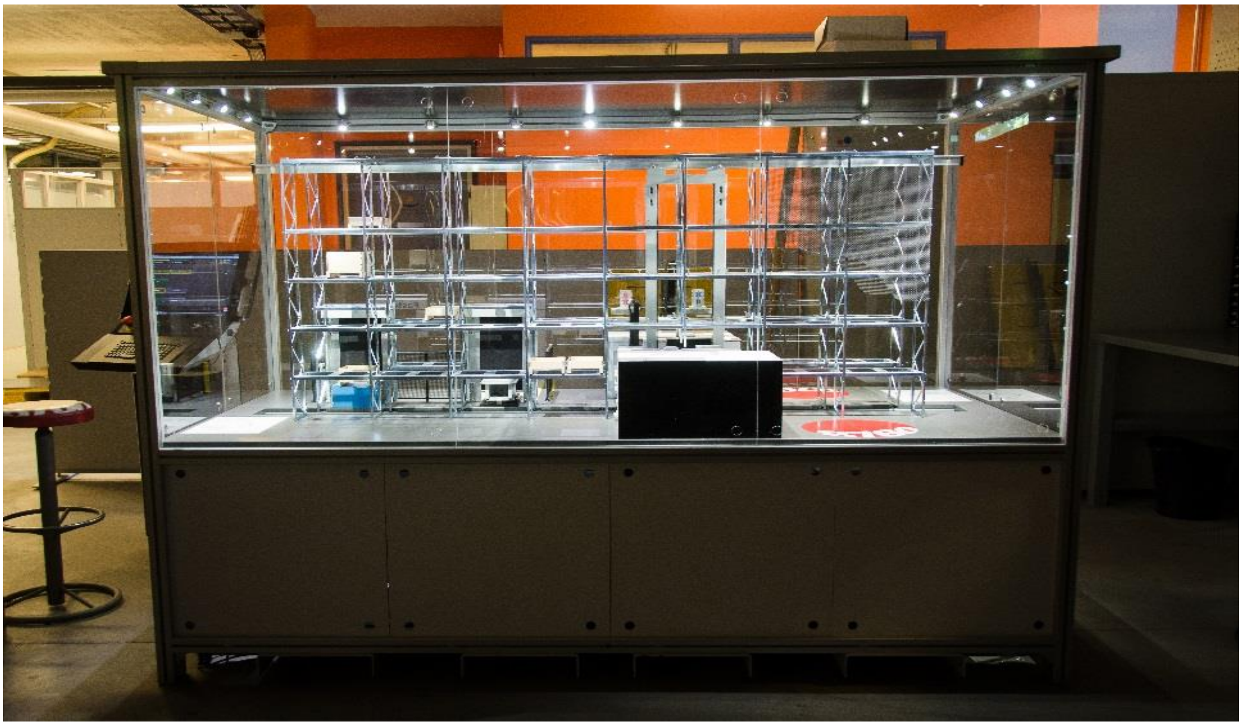

Figure 3. Pilot model of Fastem FMS, made by students from TUAS and TAI

Although we consider this project very successful, there were many features and problems, which were discussed above. E.g. time schedule was very critical in many phases, there were some troubles with sub-contractors and components, etc.

6. Conclusions

Co –operation with industrial companies and Universities of Applied Sciences is a very important part of learning today. You can get state- of- the- art knowledge form companies and the students will learn how to deal with real life problems and tasks. In TUAS the co-operation between companies and university has strongly increased in last years. TUAS has a significant role in offering students the possibility of taking apart in many important projects. The quality of co-operation has also increased during the years. We have found together many practical ways to co-operate. Still there are left many ideas and innovations which can lead even better results.

7. Acknowledgements

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An Inter-campus, Multi-disciplinary, Industry Sponsored Capstone Design Project on VTOL

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Abstract

In the past three years, the Boeing Company has sponsored a multidisciplinary, inter-campus senior capstone design project to design a futuristic vertical take-off and landing (VTOL) aircraft based on probable technologies available for production in 2040. Each year, students from Iowa State University (ISU) and North Carolina A&T State University (NC A&T) team together to work a on a different VTOL project. Each year, two collaborative teams of students from ISU and N.C. A&T are formed to compete. Each team has 7 aerospace engineering seniors from ISU and an equal number of students from N.C. A&T (from three departments: mechanical engineering, industrial engineering, and electrical engineering). Students gained valuable experience through this challenging project.

Keywords: *Capstone design, multidisciplinary, industry-sponsored project*.

1. Inter-campus Capstone Design Project

Industry-sponsored capstone design projects has been an effective method of achieving open-ended, real world, multidisciplinary, and team-based design experiences [1]-[3]. In the past three years, the Boeing Company has sponsored a multidisciplinary, inter-campus senior capstone design project to design a futuristic vertical takeoff and landing (VTOL) aircraft based on probable technologies available for production in 2040. Each year, students from Iowa State University (ISU) and North Carolina A&T State University (NC A&T) team together to work a on a different VTOL project: Medical Evacuation VTOL in 2012, High Rise Rescue VTOL in 2013, and Personal Air Vehicle (PAV) VTOL in 2014.

The Aerospace Engineering Department at ISU is a large department with over 800 undergraduate students, while Mechanical Engineering Department at NC A&T has about 300 undergraduate students. ISU's Aerospace Engineering Department ranks top 20 in the nation. NC A&T is one of the nation's Historically Black Colleges and Universities (HBCU), and has been the nation's leading producer of African American engineers. The two universities are separated by a distance of over 1000 miles.

Each year, two collaborative teams of students from ISU and N.C. A&T are formed to compete. Each team has 7 aerospace engineering seniors from ISU and an equal number of students from N.C. A&T. The majority of students from N.C. A&T are mechanical engineering seniors (many of them are in aerospace option) along with industrial engineering seniors and electrical engineering seniors. The interdisciplinary makeup helps students tackle this challenging project.

In the beginning of each academic year, the project starts with a virtual kick-off meeting using videoconference facility in both campuses and Boeing. This is followed by an on-site kick-off meeting at Boeing's Philadelphia facility in early September. The kick-off meeting provides an opportunity for students from two universities to meet face to face, setting the stage for long-distance collaboration afterwards. Additionally, in this kick-off meeting, Boeing gives several presentations on VTOL and a tour of its wind tunnel facility and helicopter production facility. Following this on-site meeting, Boeing offered several teleconference seminars to address additional background information on VTOL.

There are two formal design reviews in the form of design competitions of the two teams (blue and white): a conceptual design competition in November and a final design review with a prototype VTOL demonstration/competition in April. These two design reviews are held on alternate college campuses. Students

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were judged on designs and technical demonstrations by a panel of experts from Boeing along with professors from both universities.

2. VTOL 2040 Projects

The VTOL project is based on probable technologies available for production in 2040. Students are encouraged to explore how things are like 25+ years from now, and the trend of applicable technology headed. To help the design process, students are required to use QFD (Quality Function Deployment) diagram to lay out what's and how's, and are urged to use Systems Engineering V model to go through the steps of requirements formulation, concept generation and selection, trade studies, preliminary and detailed design, as well as component and subsystem test and integration.

The overall system architecture of this VTOL project is divided in five subsystems (focus areas). The four focus areas that are common to all three VTOL projects are:

- Lift / Propulsion / Aerodynamics
- Structure / Landing Gear
- Flight and Guidance Control System
- Communications and Navigation Systems

The mission specific focus area in each year is:

- Medevac – Cabin / Patient Area / Medical
- Urban High Rise Rescue – Services Rescue system and compartment
- PAV – Roadable Characteristics (ground transportation and storage)

The VTOL project also specifies key performance requirements in each year. In the 1st year, Medevac VTOL 2040 is required to:

- 100 nautical mile (nm) mission radius to recover (2) personnel in (1) hour back to base facility
- Stabilizing medical services to be available in aircraft, and medical communications to receiving doctors required from point of recovery to medical facility delivery

In the 2nd year, key performance requirements of the Urban High Rise Rescue VTOL 2040 are:

- Rescue up to 6 people per trip from the side of a high rise building, urban setting
- Deliver rescued people to disaster relief coordination site up to 1 mile away
- Conduct at least 5 trips before 'refuelling' required
- One on-board rescue crew member with limited/no pilot skills,
- Aerial deployment to rescue site, up to 10 miles from storage at a regional first responder facility
- No carbon-based emissions allowed from the aircraft

In the 3rd year, key performance requirements of the PAV VTOL are:

- Transport up to 4 people per trip from point to point of at least 60 miles in range
- The vehicle shall be "roadable", fit within a single lane, and capable of driving in neighborhood settings to available take-off and landing sites (35 mph max speed)
- The vehicle shall be capable of fitting into a single car garage spot
- Take-off and landing sites shall be no larger than 50 feet in diameter, and the aircraft shall be able to fit within that area during take-off and landing
- Vehicle shall be driveable/flyable by automobile driver's license holders after 40 hours of additional education and instruction
- Refuelling and/or charging shall occur in no more than 2 hours' time
- 80% of PAV materials by mass shall be recyclable. Environmentally hazardous materials shall make up no more than 5% of the PAV mass.

3. Prototype / Demonstrator

The project culminates in a final design review with a technology demonstration. Scale model prototypes of the VTOL are built as shown in the following two figures. Figure 1 shows the flying drone of one model in year 2,

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and Figure 2 shows its CAD model and the drone skeleton. Figure 3 shows the CAD model, CFD model of a competing design in the same year. Figure 4 shows the rescue drone.

Figure 1. Rescue VTOL-3 Rotors

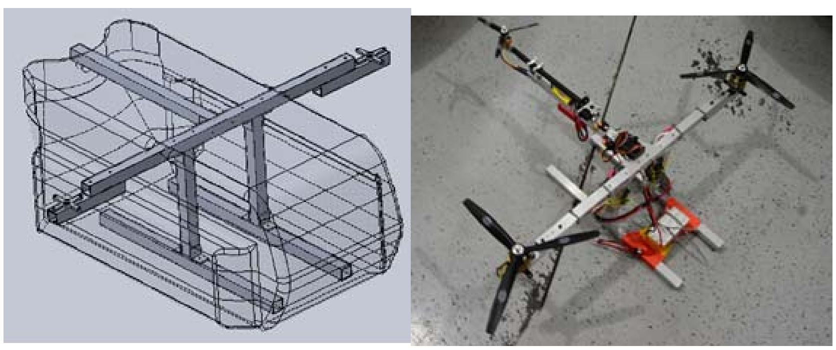

Figure 2. Rescue VTOL-3 Rotors

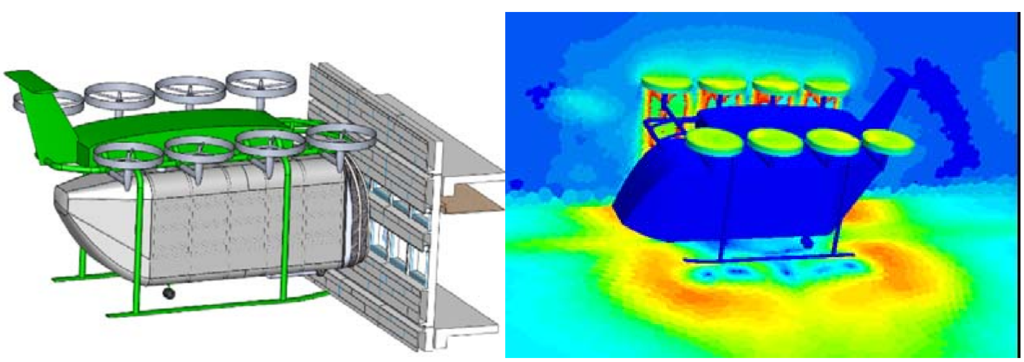

Figure 3. Rescue VTOL-8 Rotors

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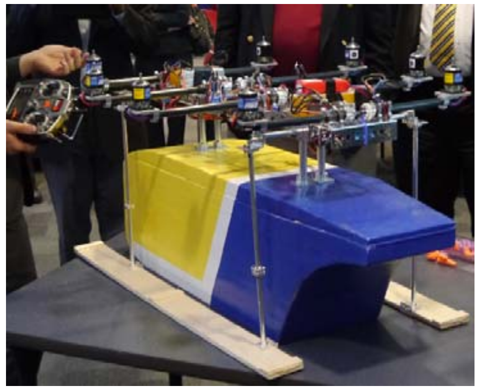

Figure 4. Rescue VTOL-8 Rotors

4. Discussion

The ubiquitous quadcopter drones nowadays has fuelled the interest of this project and made the prototype building easier. However, FAA rules [4] - [5] on flying the drone on campus severely limit locations to test the prototype.

The multidisciplinary project, with team members from four majors in two universities, is a significant and challenging project to students. They all gained valuable insights on team work and project management through this project. The inter-campus aspect of the project, however, cannot be easily duplicated because of high travel costs, as the two universities are separated by a distance that necessitates air travel. Without corporate funding, it is highly unlikely the project will be able sustain in the current format.

5. Acknowledgement

The Boeing Company's continual funding and technical guidance for this project is greatly appreciated

6. Conclusion

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7. Acknowledgements

The acknowledgement for funding organizations etc. should be placed in a separate section at the end of the text.

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LINC Project for Enhancement of Industry-University Cooperation in Engineering Education in South Korea

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Abstract

South Korea has achieved a rapid economic growth over the past 40 years and engineering education is evaluated as contributing greatly to such economic growth of the country. However, the engineering education of the South Korea is now experiencing many challenges. Typically, there is unbalance between engineering manpower and its industrial demand, top students tend to avoid choosing engineering, and companies raise problems on engineering curricula's failure to reflect latest technologies. In this paper, we present one of the government's major projects related to engineering education - LINC (Leaders in INdustry-university Cooperation) program which was launched in 2012 to enable university education to respond effectively to industrial needs through industry-university cooperation. Dongguk University was selected for this program since 2012. Through Dongguk University's example, we will introduce on the establishment of industry-university cooperation-friendly university system and the construction of components for the improvement of education.

Keywords: *LINC, Industry University Cooperation, Engineering Education,*

1. Introduction

The modernization of South Korea has begun since 1960s. Labor-intensive light industries were initiated in 1960s through efforts on recovery of social infrastructure to restore economic collapse caused by the Korean War which lasted for 3 years from 1950. From 1970s to 1980s, the government of South Korea hardened foundation of capital-intensive heavy and chemical industries. The education frameworks of technical high schools and engineering-centered universities were established to nurture skilled manpower who could support such industries. Between 1990s and 2000s, electronics industry and high-tech industries that required advanced skills began to be developed. Also, engineering universities with special purposes, such as industrial universities were founded. Since 2000s, knowledge-based convergence industries have begun. Further, universities and higher education facilities have started restructuring as a results from decrease in school age population which was caused by the diminution in population growth [1]. Such continuous growth in industry has increased GDP from USD 79 in 1960 to USD 26,205 in 2013 [2]. In case of 4-year-universities, there were around 150,000 students attending 71 universities in 1970 which was expanded to about 2.1 million students of 188 universities in 2013. Also, regarding junior colleges, there were 65 colleges with 33,000 students in 1970, and increased to 140 colleges with 760,000 students in 2013 [3]. Engineering deserved credit for such tremendous economic growth of South Korea to large extent. The strategy of South Korea for economic development through intensively fostering engineering is well shown in related statistical data. Table 1 indicates the statistical figures of engineering in 4-year- universities and junior colleges in 2013 [3].

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Table 1. Statistics on Education

		4 year Universities	Junior Colleges
Institutions		188	140
Number of Students	Total	2,120,296	747,721
	Engineering	551,630	228,615
Number of Professors	Total	63,042	13,015
	Engineering	13,966	3,765
Employment Ratio	Total	55.6%	65.6%
	Engineering	67.4%	61.2%

As shown in table 1, the number of students majoring in engineering takes up 26%, which is significantly higher than 12% of students studying engineering in EU countries. However, the engineering education of South Korea has encountered various challenges since 2000s. For example, imbalance between industrial demands and the number of trained engineering manpower, dissatisfaction with engineering education, preferences of excellent students on non-engineering majors, decrease of science education curriculum in high schools, and the avoidance choosing engineering major. The government is currently providing various policies to improve competitiveness of engineering education [4][5]. This article has examined LINC project - the largest government's support projects to improve engineering education which leads to cope proactively with changes in the industrial structure to boost national competitiveness.

2. LINC Project

2.1. LINC Project Overview

LINC project has been led by the Ministry of Education to reinforce university education to cope with industrial demands through industry-university cooperation. LINC project was initiated with 51 universities from 2012 to 2013 as the first stage. In the second stage, begun in 2014, the project was expanded with budgetary support of KRW 240 billion (USD 240 million) to 56 universities and 30 junior colleges nationwide. The main objective of LINC project is to support linkage between universities and local industry actively. To achieve this, each university should set up their own strategies which take into account of local industry conditions and university's competence, and select the specialized areas connected to local industries to focus their competences on manpower training and technology development. The basic concept for LINC project is shown in figure 1.

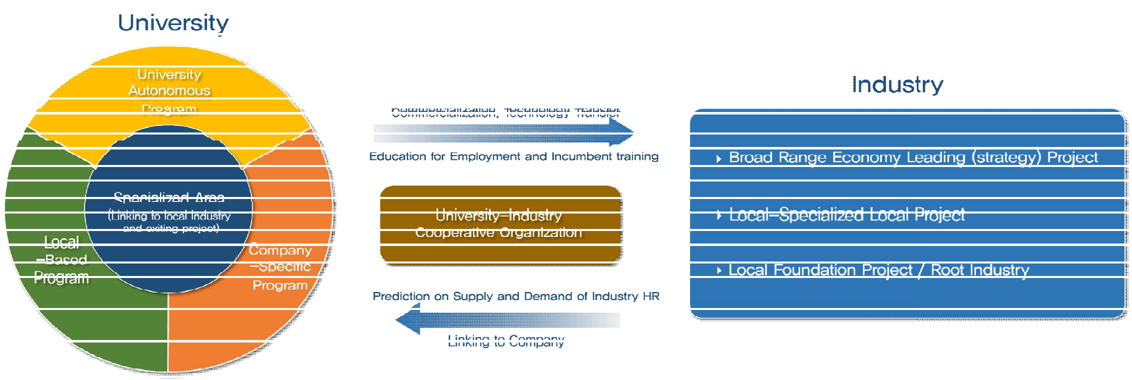

Figure 1. Basic concept for reinforcement of linkage between university and local industry

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The major contents of LINC are classified into four categories: vision, system, component, and link. In 'vision' area, the specialized area considering the characteristics of university and local industry is set and project goal is established accordingly. After that, short-and long-term strategies and each year's performance and expected results are proposed. The detailed unit programs to realize the vision are suggested in system, component, and link areas. The main objective of 'system' area is to transfer university system to industry-university cooperation-friendly system. In specific, faculty evaluation system should reflect the professor's performance on industry-university cooperation. Also, the university should recruit the professors with enough experiences in industries called industry-university cooperation specialized professor. Moreover, the university should have organization to support for business foundation and field training. The field of 'component' draws up plans to nurture skilled manpower to reinforce industry-university cooperation, reform and operate university curriculum for industrial demands, support specialized employment and entrepreneurship education in accordance with the types of local industry. Last, the 'link' area expects to operate various business support programs to reinforce competitiveness of community and local enterprises.

2.2. Overview of Dongguk University's LINC project

Dongguk University is a 4-year private university located in the center of Seoul, the capital city of South Korea and has 109 years of history. Currently, it consists of 11 colleges with 57 departments, and the number of students accounts for as to 12,000. Dongguk University has long history in the field of humanities and art. Recently, however, its academic areas are being expanded centered at engineering majors and consequently, number of students and professors occupy 1/4 of the entire university. Further, Chungmuro area of Seoul, in which the University is located, consists mainly of urban-type industries including finance, printing, movie and digital contents. The Dongguk University's LINC project team, accordingly, has set the project vision as 'Building urban & global industry-university cooperation system through convergence of humanities, art, engineering and entrepreneurship'.

The LINC project team of Dongguk University consists of industry-university HR training center, industry-university enterprise support center, field training support center, entrepreneurship education center, D-CUBIC specialization center, and administration office. In addition, 19 departments (major) of 8 colleges and about 6,000 students participate in this project. The number of students participating in LINC project of Dongguk University occupies 48% of the entire students, meaning that the LINC project is being regarded as a major project of Dongguk University. LINC project team of Dongguk University operates various detailed projects, which comply with the vision, system, component and link area. The core projects are indicated in figure 2.

Figure 2. Dongguk university LINC project – major programs

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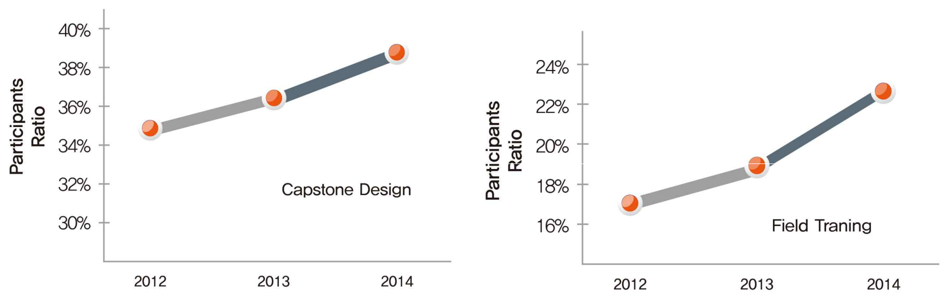
3. Performances of LINC Project Team of Dongguk University

The LINC project team of Dongguk University has been creating various achievements through the projects performed for the last 3 years. In system area, industry-university cooperation activity is recently added to traditional faculty evaluation categories such as education, research and service. Typical examples of industry-university cooperation activities include the registration of intellectual property right, technology transfer, and field training instruction. Also, the reflection score of industry-university cooperation activities is more weighted than other evaluation categories to induce active participation of professors in this area. As a result, the performance ratio of industry-university cooperation area for faculty evaluation has increased from 14% in 2013 to 24% in 2014. In component area, the industrial demands have been reflected actively for development of curriculum, and expansion of employment and entrepreneurship program. The ratios of students who participated in capstone design and field training had increased to 38.3% and 22.4%, respectively. Figure 3 shows the increase of the participants ratio of capstone design and field training during 2012~2014 period. This has led to increase in employment rate too. Especially, the employment rate of students who participated in field training program is shown 21% higher in average than that of non-participative ones. Figure 4 shows the difference of employment rates between those groups of students.



(a) Capstone Design (b) Field Training

Figure 3. The ratio of students who participated in capstone design and field training

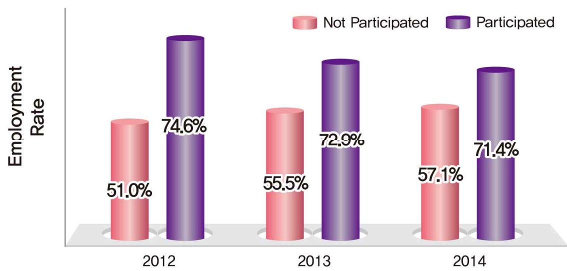


Figure 4. Comparison of the employment rate of students

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In link area, 733 “family companies” have been constituted. These companies achieved qualitative growth through various unit programs with professors such as technology development, customized enterprise instruction, and shared equipment supports for product development. Through these activities, virtuous circulation structure of industry-university cooperation such as employment and field training at the family companies has been constructed. In the next chapter, the three representative Industry-University cooperation cases are presented.

3.1. ICIP & ECIP

ICIP (Internship & Capstone design Integrated Program) and ECIP (Enternship & Capstone design Integrated Program) are Dongguk University’s specialized industry-university cooperation programs. Both programs are aimed to 3rd and 4th year students. The main objective of ICIP is to solve the actual tasks presented by companies. The task which a participant company proposes is dealt with in teams during the capstone design course, half or one year, and field training is implemented by the company for 2 months during summer vacation. This program is aimed to provide field experience to students without delaying their graduation schedule. It also increases the employment opportunity. Meanwhile, ECIP is to seek the future business founder through improvement of students’ challenge spirit and capability for entrepreneurship. In this program, each student or team who is interested in business foundation completes capstone design course for a semester or a year with their ideas to solve technical, managerial and marketing problems required for business foundation, and take part in entrepreneur internship (Entre-ship) during school vacations. Figure 5 shows conceptual scheme of these programs.

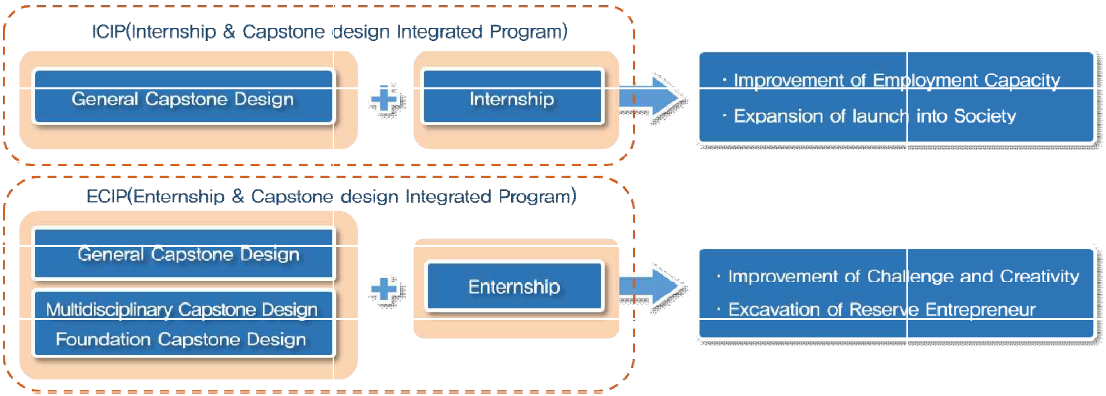

Figure 5. ICIP & ECIP

ICIP program was initiated for the first time in 2011. The first program started in cooperation with LG Electronics which is a representative company of South Korea. 26 out of 60 students who participated in the program succeeded in getting a job in LG Electronics. In 2012, 8 students carried out 2 tasks presented by LG Electronics, and 39 students participated in 13 tasks presented by other middle/small-sized companies. In 2013, 13 companies participated along with 21 tasks and 79 students. In 2014, 14 companies participated along with 19 projects and 70 students. The employment rate for those students who participated in the ICIP was 100%.
ECIP started as a pilot program in 2014 to operate a full scale program in 2015. Unlike ICIP, the number of students participating in ECIP program is small yet. The program is designed for students who want to start their own business rather than finding jobs, and it will be expanded to support students who are with entrepreneurship for business foundation. All of ICIP and ECIP programs are known for examples of excellent performance, and many universities in Korea have already been developing or adopted similar programs.

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3.2. Trans-media One Stop program

Trans-media one stop program is a good example for convergence education in Art, Management, and Engineering, which are designated as the specialized education areas of Dongguk University. The objective of this course is to nurture trans-media producers with knowledge on ASMD (Adaptive Source Multi Device) and CT (Culture Technology). Trans-media one stop program is classified into education for learning theoretical knowledge related to trans-media and the course for obtaining experiences in patent and commercialization.

Trans-media one stop program started as an interdisciplinary program in college of Liberal Art and became a concurrent major degree course. For this major, in 2014, four theory-based courses and two project courses were developed and being operated. The current theory-based lectures include 'Creative imagination and convergence of culture technology', 'Understanding trans-media', 'Art and management', and 'Understanding digital storytelling'. All courses include education contents in which engineering, art and management are converged. The project performance courses include 'Dongguk mobile App development in practice', 'Development of 4K digital drama and documentary'. In this program, students from different majors participate as convergence team. In the 2nd semester of 2014, 253 students took these concurrent major courses. They led to five student patents, 12 applications of "Apple" and "Google player" which were made through these project courses.

3.3. Local Community Linked Entrepreneurship Capstone Design program

The 'Local community linked entrepreneurship capstone design' program is developed to nurture students' social entrepreneurship. A specific example includes projects performed in 2014 for traditional market revitalization. Dandae market, located in the suburb of Seoul, is a traditional market of South Korea with long history, but has been deteriorated due to the modernized commercial supremacy. Students advance through this program by analyzing problems and proposing solutions on their own to strengthen the merit of traditional market and make it more competitive. First, the LINC project team of Dongguk University establishes alliance with Dandae market and SEMAS(Small Enterprise And Market Service), a semi-governmental organization, to support students to perform projects. Based on this, the 'Local community linked entrepreneurship capstone design' program started as a pilot program with KRW 64.5 million (about USD 60,000) grant from Shinsegae Group which has modernized distribution channel. There have been total 110 students participating in this program, and mentors composed of professors of engineering, design, business foundation, and external professionals supported them. Above all, students are divided into 6 teams and each team takes activities such as development of traditional market contents, activation of space for entertainment, taste specialized product development, public art, modernization of facility and ICT activation of traditional market to revitalize Dandae market. The student has proposed 13 projects and their outcomes from this project results in 10 awards in the various internal/external competitions and registered six intellectual property rights. Especially, in 2014, the excellence of this program was introduced in the World Design Management Forum and industry-university cooperation festival held in South Korea. This program is an education program connected with universities, local industries, major governmental organizations, and it is very meaningful for university and enterprises to perform social responsibilities through solving actual problems of the local society together.

4. Conclusion

The colleges of engineering in South Korea have been leading the rapid economic growth in 1970s and 1980s, but it is often pointed out that they have not played enough roles as the leader of industry since 2000s. However, the government and society all share the idea that nurturing the engineering education is the key for sustainable economic growth of South Korea. Accordingly, the government of South Korea has made various plans to make the colleges of engineering as the driving force of industry. The LINC project discussed in this paper is a good example of this type of governmental project. Since the introduction of LINC project in 2012, outcomes of 51 universities indicate that there are tremendous increases in various education activities related to industry-university cooperation [6]. For instance, the ratio of the number of students who take field training and capstone design course increases considerably. In addition, the development and operation of industry-university cooperation related education curriculum is increased around 100%. As a result from this active industry-university cooperation, amount of technology transfer is also increased. It also helps to solve problems of imbalance in manpower supply and demand by nurturing students with experience that industries require. The LINC project team of Dongguk University trains human resources and develops technology through operation of various programs in which humanities and art have been converged with engineering. The results are selected as excellent examples and are being distributed to other universities and governmental projects. As indicated, cooperation between the government, universities, and industries for development of industry-friendly engineering education program will help regain their positions as the framework for the national growth.

5. Acknowledgements

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A Model for Global Collaborative Engineering Education in Product Data Management

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Abstract

Over the last decade, five universities around the globe have been collaborating in the teaching of a course on product data management through design. The universities are Howard University and Virginia Tech in the USA, ITESM in Monterrey Mexico, Technische Universitat Darmstadt, Germany and Shanghai Jiao Tong University, China. In addition to introducing the students to working across continents on a design project in global teams, it brings the students together to understand each other culturally and to bring this union to bear on the major engineering design project which is constrained to satisfy customer needs in different world markets. The course is taught under the global umbrella of the Partners for the Advancement of Engineering Education (PACE) that has generously provided some resources to enhance the delivery of the course. In this paper, a general description and history of the course is presented followed by specifics related to the planning, organization and conduct of the single semester course. The resources for the course are described in addition to the conduct of the course over the thirteen week semester period. Examples of students' work are presented in the paper. The paper concludes with achievements, challenges from the collaboration and provides recommendations for the enhancement of the course.

Keywords: *Globalization, Collaborative, Engineering Education, Product Based Learning*

1. Introduction

Engineering education continues to evolve with the passing of time due for the most part to the availability of high speed communication instruments and computer aided tools in product design. In the current digital age and the role of computers in the future, it is essential that engineers of all disciplines have a good understanding and working knowledge of the fundamentals of digital systems as well as fluency in using contemporary computer systems and tools. In addition to strong analytical skills, the engineer must possess the ability to exploit computing and simulation technologies in the modelling and creation of new engineering products [1]. The computer based design-build engineering process, such as was done with the Boeing 777 [2], will become the norm for most product designs, thereby accelerating the creation of complex products for which multiple subsystems combine to form a final product. As part of the design process, there are a number of companies that provide software tools that allow for the creation of a model, meshing the model, and performing finite element analysis on the model to ensure that it meets the design criteria. Software technology exists today for use in the analysis and design of single as well as multi-physics problems in which fluid flow and heat transfer may be coupled to structural interactions. Institutions of higher learning that are able to exploit the available technology in a multi-institutional environment globally will be able to better prepare students for the global work environment that has evolved in recent years.

In addition to software technology for the design and analysis of engineering systems, the use of software for the complete life cycle of a product from the “cradle to the grave” is on the rise in most multi-national corporations such as General Motors and Proctor and Gamble. A number of books, for example Grieves [3], have been written on the process of “managing” the life cycle of a product which takes advantage of the internet for use in sharing data among designers and product managers across different continents in different time zones. To keep up with industry practices and to better prepare students for the global environment that has become very competitive, students must be introduced to be able to use the various technology tools that will keep them “ahead of the curve” for them to gain meaningful employment and be productive in any working environment. It is for this reason and others (both internal and external) that the curricula of engineering departments must be dynamic in which changes are made continuously in order to satisfy industry, accreditation and other requirements. The mechanical engineering department at Howard University is no exception and over the years, the faculty have worked assiduously to include internal and external factors in the design and delivery of its curriculum.

This paper describes the efforts of the faculty, external partners and other stakeholders in five global universities in the implementation of a model to teach product design in a product data management environment. The emphasis of the paper is on the use of technology to teach a course on product design to a global team of students within the constraints of the traditional university environment. Beginning with a historical perspective of the mechanical engineering curriculum at Howard University, Washington DC, USA, the paper describes various initiatives to achieve the goals and objectives as stated for accreditation purposes. Since the receipt of a major in-kind donation from the Partners for the Advancement of Collaborative Engineering Education (PACE) in 2004, the department has made progress in integrating the industrial level suite of engineering software tools that are provided by the PACE organization. Following a description of the PACE award, the paper presents the various aspects of the delivery of the global course, Product Data Management. Examples of students' work in the enrichment process are presented in the paper. The paper concludes with recommendations for enhancing the course among the participating global institutions.

1.1. Product Data Management

Product Data Management (PDM) is a derivative of Product Lifecycle Management (PLM) which has become a discipline by itself as the newest wave in productivity. This approach to production resulted from "lean thinking" in the planning and production of products. As presented in Grieves [3], PLM eliminates waste and maximizes efficiency across all aspects of a product's life –from the design of the product to its retirement-not just in its manufacture. The main goal of PLM is to use resources such as people, product information, processes, and technology to reduce time, energy and other materials across an organization and in the process achieve a high level of production efficiency and ultimately profitable.

The elements of PLM, as adopted by Siemens Corporation [4], are depicted pictorially in Figure 1 and include traditional academic engineering subject areas such as Design, Simulation, Machining and Manufacturing, Robotics, and Assembly. The other areas listed are also taught in traditional academic degree programs such as Industrial Engineering, Industrial Design, and others in Business Schools. In this paper, Product Data Management (PDM) will be considered a subset of PLM and will be limited to those subject areas that are taught in a typical traditional mechanical engineering program. The implementation of any PLM or PDM system depends heavily on the use of technology and reliable and accurate software packages that can be used in the design, simulation, manufacturing, visualization, animation, and all other aspects of the design process in order to realize a working prototype of a product. The product can range from the design of an ankle clip to as big as the Boeing 777 aircraft. The cost of such systems to engineering educational programs can be prohibitively expensive and unaffordable; with the generosity of the PACE organization [5], however, a number of universities including Howard University have become recipients of in-kind donations that include hardware and industry level software programs. A description of the technology infrastructure resulting from the award of such a grant is presented in the paper.

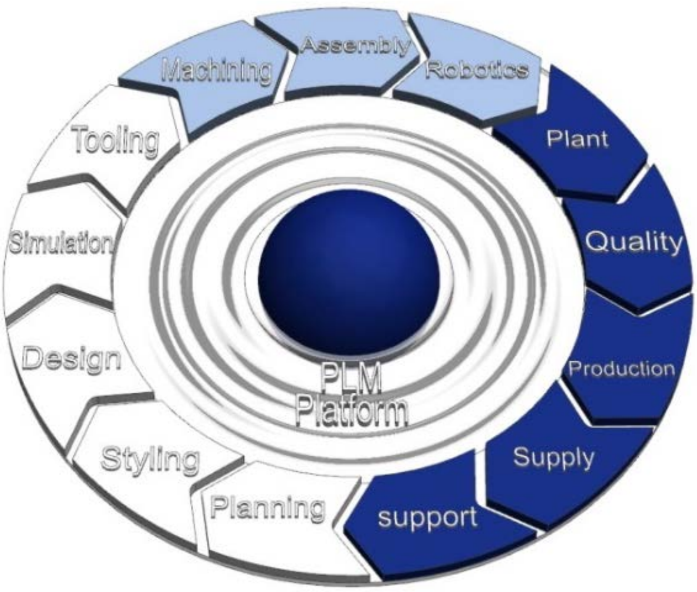

Figure 1.Elements of Product Lifecycle Management [4]

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1.2. Problem-Based Learning

The global course, PDM, as taught among the institutions, relies on the results of research that have been conducted and reported on Problem-Based Learning (PBL) which in itself is a form of Evidence Based Learning (EBL). Evidence-based learning (EBL) is a total approach to education that utilizes methods based on significant and trustworthy evidence that has been obtained from experiments. The goal of this education method is to apply available evidence to educational decision making in various fields of study including, but not limited to, engineering, medicine, and business. Evidence-based learning is not a tangible item, nor does it aim to produce tangible goods. It does, however, allow students to learn and make connections “through active experimentation in the environment, observation, and reflection,” according to Vosinakis & Koutsabasis [6]. Evidence-based learning can occur in groups or in a one-on-one teacher-student setting. Evidence-based teaching is a method that aggregates best teaching practices. These “best” teaching practices are labeled as such based on empirical evidence, student reviews, evaluations of the teaching method, and assessments of the students’ retention or understanding of the learning objectives of the course. Some of the methods that have been shown to work significantly better than the traditional lecture-style approach are: using analogies and similes, cooperative learning, note making and summarizing, and graphical organizers and methods.

Problem-based learning, a focused category of evidence-based learning (EBL), is being adopted by educators in the engineering field in attempt to better prepare students to solve complex, real-world problems. Vosinakis &Koutsabasis [6] state that, “Problem-based learning is regarded by many as a total approach to learning, as a philosophy about learning and as a learning strategy, rather than simply a method of teaching.” Khan et al [7] state that “PBL is a learner-centered approach that empowers learners to research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem.” These skills that PBL empowers are at the root of engineering. Throughout most engineering curricula, students have to find abstract solutions to concrete problems. Khan et al [7] also state that for PBL to be most effective, students must be responsible for their own learning, students have to be able to think critically to define the problem; problems should have a real-world application, and that self and peer assessments should be done regularly. In this regard students are able to learn through their collaborative work to solve some ill-defined authentic problems.

In PBL, students work in small collaborative groups and learn what they need to know in order to solve a problem. The teacher acts as a facilitator to guide student learning through the learning cycle. In this cycle, also known as the PBL tutorial process, the students are presented with a problem scenario. They formulate and analyze the problem by identifying the relevant facts from the scenario. This fact-identification step, Hung et al [8], helps students represent and define the problem with clear specifications and constraints. As students understand the problem better, they can create hypotheses about possible solutions. An important part of this cycle is identifying where students lack the knowledge needed to solve the problem. These knowledge deficiencies are major issues that students tackle during self-directed learning and in consultations with instructors.

With respect to students’ retention of content, research on PBL has revealed that in terms of short-term retention, no difference was determined between PBL and traditional (non-PBL) students, Gallagher [9] and Dochy et al [10]; however PBL students consistently outperformed traditional students on long-term retention assessments. Studies reveal that PBL students’ recollection of basic principles was up to five times greater on basic concepts relative to traditional students 6 months after the course was completed. Recently, Yadav et al [11] reported a research study they had conducted on the impact of problem-based learning (PBL) on undergraduate electrical engineering students’ conceptual understanding including their perceptions of learning in a PBL environment as compared to the traditional lecture format. In spite of the shortcomings of the study, results suggested that the participants’ learning gains from PBL were twice the gains from the traditional lecture. It is concluded from the review of the literature that even though PBL students may score slightly less on factual knowledge, they retain more of the acquired knowledge as compared with the traditional students. The latter results from the fact that PBL students developed more elaborated knowledge due to the attention for the elaboration of concepts in PBL and hence are able to better recall the knowledge.

1.3. Historical Perspective

In the mechanical engineering program at Howard University, Washington DC, USA, students are required to complete a minimum of 128 credit hours and achieve a minimum grade point average (GPA) of 2.0 in order to receive the degree, Bachelor of Science (BS) in Mechanical Engineering. Prior to the year 2002, the requirement ranged from 143-145 credit hours depending on the selected technical elective. The current curriculum is structured into four main core threads: a social science/humanities thread; a thread involving mathematics and engineering science; a thread with a focus on laboratory experimentation and a thread that involves the integration of design in the curriculum.

Based on a four-year completion scheme that is used by the department to guide students through matriculation in the program, the scheme requires students to take a minimum of 23 credits in social sciences/humanities, 68 credits in mathematics and engineering science, 9 credits in laboratory experimentation and 22 credits in courses that focus on engineering design. To give students room to pursue interests in preparation for graduate school or to enhance their entrepreneurial skills, students are given the chance to obtain 12 credit hours in a combination of technical electives (selected from the mechanical engineering curriculum) and “free electives” for which departmental guidelines exist for the selection of such courses. One of the technical electives available to students is the course, Product Data Management, which is the focus of this paper.

2. Technology Infrastructure

A modern and current mechanical engineering curriculum requires that both faculty and students have access to the technology in order to implement computer assisted design and analysis processes to enhance teaching and learning. In generic terms these tools and processes are labelled as Computer Aided Design (CAD), Computer Aided Engineering (CAE), Computer Aided Manufacturing (CAM), and Product Data Management (PDM).

In October 2004, following an introductory qualifying period, Howard University officially became a member of the organization known as Partners for the Advancement of Collaborative Engineering Education (PACE). PACE links General Motors (GM), Autodesk, Hewlett Packard (HP), Oracle, Siemens PLM Software, and their global operations, in the support of strategically selected academic institutions worldwide, to develop primarily the *automotive product lifecycle management* (PLM) team of the future. PLM, as it relates to PACE, is an integrated, parametric-based approach to all aspects of a product's life-from its design inception, through its manufacture, marketing, distribution and maintenance, and finally into recycling and disposal [5]. Currently, PACE is focused on:

- ☐ Requirements and planning (concept development)
- ☐ Styling (conceptualization and product design)
- ☐ Product engineering (vehicle and powertrain detailed engineering design)
- ☐ Simulation (validation, optimization)
- ☐ Manufacturing engineering (tooling, machining, 3D plant layout)
- ☐ Managed development environment (product data management, supply chain collaboration, digital collaboration)

As a member of PACE, Howard University received donations of computer hardware, accessories and industry level software valued at over seventy million dollars. The suite of software currently offered by PACE for engineering design and analysis include NX (formerly Unigraphics), ANSYS FLUENT, software from MSC including NASTRAN, DYNA, software from Altair HyperWorks, Autodesk software, Alias and others. Based on the needs of the automobile industry, the two departments that are the primary beneficiaries of the software are the mechanical engineering and the art departments. As a result, the university has two PACE laboratories on campus that contain the hardware and software dedicated for PACE activities and for instructional activities in the execution of the curricula of the two departments. Beyond the initial award of hardware and software in 2004, PACE makes available on a competitive basis additional hardware to its partner institutions on a yearly basis. Through these yearly offers, Howard University has received additional hardware and monetary grant awards for the development of courseware and for the purchase of equipment for communication among other universities globally.

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3. Utilization of PACE Software

The curriculum of the mechanical engineering department is structured so that in addition to learning the basic engineering and science courses, students are exposed to engineering design vertically across the curriculum from the first to the final year. In the first year the mechanical engineering students are expected to enroll in Engineering Graphics (currently called Introduction to Computer Aided Design) and as revised, the students will also take the new course, Introduction to Mechanical Engineering in the second semester. These are in addition to the course, Introduction to Engineering, that is required to be taken by all entering (freshmen) engineering students. In the second year, the students are expected to take the course, Introduction to Engineering Computations, with the potential to apply the knowledge gained in solving problems in courses such as Statics and Dynamics. In the third year the primary courses in which the PACE software are used include the two semester courses, Mechanical Design I and II; and in the final year students execute industry-level design projects in which there are heavy uses of the suite of software. Elective courses such as Product Data Management also require students to use the PLM software from Siemens as part of the PACE award to the university.

4. Purpose of the Global Course

Within the last decade or more the word “Globalization” has become a buzz word at international conferences on engineering education. Globalization is described as “the development of an increasingly integrated global economy marked especially by free trade, free flow of capital, and the tapping of cheaper foreign labor markets” [12] Relating the definition of globalization to engineering education would simply imply that a curriculum must prepare its students to take advantage of the globalization of the economies of the world and be able to adapt to various working conditions so that they can be effective as team players in advancing the goals and objectives of their organizations which for the most part are for-profit multinational corporations. Some elements [13] of a globalized curriculum are the following:

- Part of graduation requirements could be fulfilled through a period of study road.
- Implement faculty and student exchange programs to clarify the global views of the engineering practice.
- Inclusion of extended periods and/or close cooperation with industry while enrolled in the engineering program.
- Conducting joint projects/research among various departments (multi-disciplinary) and among different universities in different geographical locations and countries.
- Engineering curricula must include languages and cultural studies.
- Engineering programs accreditation must be made global and subject to international quality standards that address industrial expectations
- Ensure that engineering students are educated in how to develop their critical thinking abilities, innovation and problem solving by offering projects at various stages of their years within the program of engineering and not just at the end of the program

To infuse global awareness into the mechanical engineering curriculum at Howard University, students have the option to take a global course that is offered as a technical elective as stated earlier. The notion for the course was conceived when Howard University became a member of the Partners for the Advancement Collaborative Engineering Education (PACE) in 2004. With the encouragement of colleagues at Virginia Tech, Howard joined a team of other PACE institutions in creating the technical elective global course on Product Data Management. This global course is taught among five universities in four countries: Virginia Tech and Howard University in the US; ITESM, Monterrey in Mexico; Shanghai Jiao Tong University, China; and Technische Universität Darmstadt in Germany. The course is taught by video conferencing and extensive use of Internet resources such as Skype for communication by students working in teams on assigned design projects. To take advantage of cultural diversity in enhancing learning and effective teamwork, each student team is formed with students from each of the countries represented in the course.

4.1. Implementation of the Global Course

As required by the PACE organizations, the teaching faculty members of the global course usually attend the annual meeting of PACE that is held in a country in which there is a presence of the automobile giant General Motors. It is at this meeting that the faculty members begin to chart a program and schedule for the course that is taught between August and December. Following such a meeting, faculty members would communicate electronically to finalize details of the course objectives, delivery of lectures and the selection of a project that would be executed under the PDM platform.

Due to the different academic calendars of the five institutions, the class does not meet until approximately the first week of October. At Howard University, lectures begin in late August or early September based on a two-semester academic year. During the period of "waiting" for the first global meeting, students are given reading assignments on PLM theory and to lead discussions of various sections of the book by Grieves [3]. The students are also asked to summarize each chapter of the book and submit to the instructor as a partial requirement for successful completion of the course. A second assignment during the "waiting period" is for students to strengthen their ability in the use of the key CAD software NX that is provided by Siemens through the PACE organization. The students rely on resources provided by Leu et al [14] and Warner and Brereton [15] to assist in their learning of the elements of the design software. A third assignment is given to the students to conduct literature search and to write a summary paper on cultural differences in engineering education among the participating countries: US, Germany, Mexico and China.

Following the "local period" of the course which lasts for about four weeks, the global class convenes in early October through video conferencing technology. Most of the technology needs to connect all the five universities are provided and managed by the Virginia Tech CAD Laboratory. The class size is approximately fifty to one hundred students in a given year with China providing the largest number of enrolled students. Following brief introductions, the lead faculty member at Virginia Tech leads the students and faculty through the technology connections and for students to log into the server (with user names and passwords assigned prior to the first meeting) that houses key software that are part of the PDM platform. From earlier communications among the faculty, students are informed of the groups they belong in the execution of a design PDM design project that is presented during the second class meeting. The global teams of students are placed in one of four teams: Buick, Chevrolet, Daewoo Patac and Adam Opel. The teams are truly global as no one institution dominates the team membership. As a three credit hour course the class meets three times a week on Monday, Wednesday and Friday. The mid-week day is reserved for lectures on related topics by the faculty and industry representatives. The other days of the week are reserved for student teams to meet and work on team projects.

4.2. Execution by Students

One goal of the class is for students to work on a project and to take cultural and geographical differences in arriving at acceptable solution(s) to the design problem. During the second meeting of the class, the students are presented with the global problem in which to make design modifications to a futuristic vehicle of GM, such as the ENV, and to design for a specific market of the world as follows

- **Team Adam Opel** (Germany)
- **Team Buick** (USA)
- **Team Chevrolet** (Mexico)
- **Team Daewoo PATAC** (China)

In the execution of the project, students use various forms of communication in addition to the PDM platform that includes Siemens Team Center Engineering and Team Center Community that are installed on a server at Virginia Tech and accessed remotely by the students. For communication students connect by video conferencing, by Skype, email, and lately by the instant messaging application Whatsapp. Cloud resources such as Dropbox and Google drive are also used by the students. For a true PDM experience however, students are urged to use the Team Center resources that are the proprietary of Siemens.

In the fall semester 2015 (August-December) student teams were charged to "design a vehicle using the General Motors EN-V 2.0 concept platform to address the customer needs in the assigned market". Each global team was divided into three sub-teams to work on Vehicle frame structure, Exterior design and Interior design respectively. As deliverables, the teams were required to submit a technical report in addition to the design of a presentation that is given on the last day of class in early December. The presentation is given not only to the faculty by video conferencing and other communication technologies but also to industry executives from the automotive industry affiliated with General Motors and the PACE organization. The presentations are judged by the industry executives who at the end of class determine the ranking of each team in the design and the effort of each team in meeting the requirements of the project. The ranking of each team is taken into consideration in the award of the final grade received by a team member. The teams use various tools to manage the project in addition to the use of CAE software that are available uniformly to all five institutions as members of PACE. Examples of the work of one of the teams are presented in Figures 2 to 4 which show pictorial view of the final product, the interior seating arrangement and the results from a finite element analysis of the frame and chassis.

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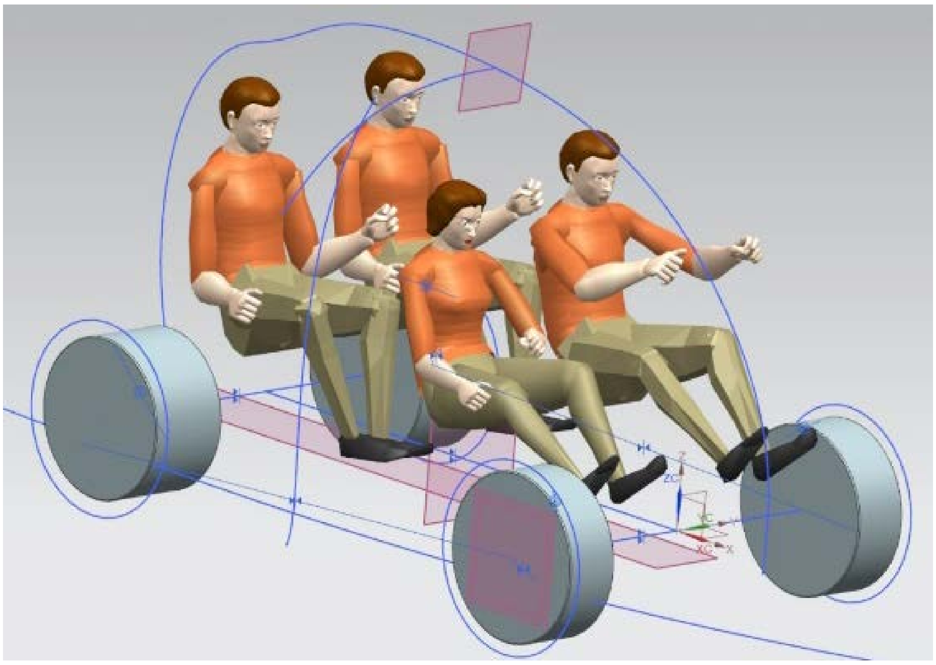

Figure 2. Interior Design of Vehicle

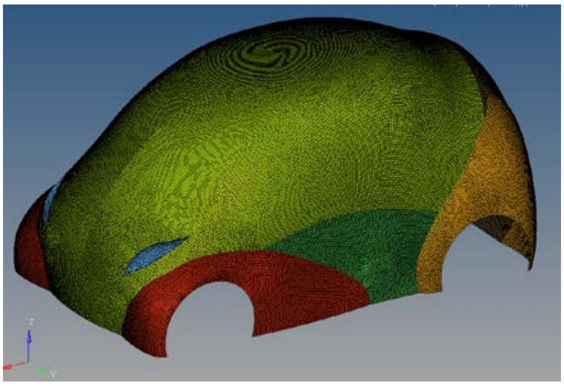

Figure 3.Vehicle Body Mesh Generation

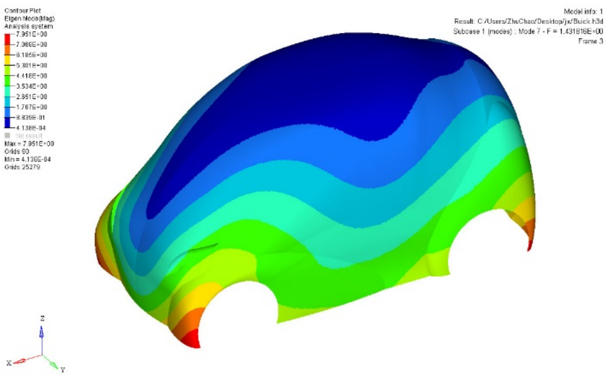

Figure 4.Vibration Analysis Results

5. Conclusion

A model for global collaboration in engineering education has been presented in this paper. The model is based on the teaching of a global course across different continents using effective communication technology in addition to CAE embedded in a product data management environment. The key features of the course involve global student teams working on a project with the support of industry and the PACE organization. In doing so the students are exposed to an industrial environment within a classroom setting and are thus better prepared to participate in the engineering of a product in a Product Lifecycle Management platform.

In spite of the benefits derived from such a course, there are some challenges that the students must overcome in working on their projects. One has to do with the cultural differences of the participating institutions; the other has to do with the time differences among the countries and finally the language barrier that may result in lack of or ineffective communication. It may be a good idea to extend the course to two semesters (one academic year) to allow the students more time to work on their projects and for them to have the chance to network and get to understand each other better in a world that has become small due for the most part to the availability of high speed communication such as the internet. As stated earlier, this course is a “technical elective” in the curricula of the participating universities. With the success of this course offering close to a decade, it may be time to institutionalize the course and require all students in each program take the course.

The benefits are tremendous and will give students the chance to be better prepared for the challenges they may face on accepting work assignments for the first time after leaving the university environment.

6. Acknowledgements

The author wishes to acknowledge the teaching faculty of the global course for their dedication in working together as a team and in the mentoring of student participants in the course year after year; and to the PACE organization for continued support of the global course. The assistance of Matthew Clarke, undergraduate student in Mechanical Engineering at Howard in formatting the paper is very much appreciated.

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Teams in Kenyan Engineering Education

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Abstract

Engineers are a critical human resource as Kenya pursues stated national goals, including the desire to achieve Newly Industrialized Country status by the year 2020. The effectiveness of Kenya's engineers and their ability to work together to design and actuate complex systems will play an increasingly significant role in Kenya's abilities to be self-sufficient and to face global competitive challenges. Consequently, engineering education and practice is of the utmost importance for Kenya's development.

Today's professional engineering environment is characterized by increasingly complex systems, accelerating rates of technological *change, global competition, and ever decreasing design-build cycles. To thrive in such an environment, engineers need abilities that complement traditional technical skills. Increasingly engineers need to be proficient with non-technical skills including communication and the ability to work in team environments. Accordingly, 'ability to work in multidisciplinary teams' is an ABET requirement for engineering graduates, and there is significant effort to instill such skills in ABET accredited schools.*

In this study we report the results of a qualitative study utilizing interviews of engineering faculty at Kenyan Universities that offer degrees in engineering. Topics covered include educational and professional background, including working in and/or managing engineering teams, and use of engineering teams in Kenyan Universities. The interviewees indicate that they believe that team skills are valuable for engineering professionals, however little to no formal programs exist for generating these skills in Kenyan engineering students. We conclude with a discussion of the necessity of team skills in the emerging engineering professional environment, and suggestions for inclusion of team skills in Kenyan Engineering education.

Keywords: *Team skills, Kenya, Engineering Education*

1. Introduction

The rapidly changing environment that engineering professionals encounter is characterized by increasingly complex systems, accelerating rates of technological change, global competition and ever decreasing timetables [1]. To thrive in this environment, engineers need more than the traditional technical skills. For today's engineers, technical skills are necessary but no longer sufficient to maintain competitiveness. Chief among these non-technical skills are communication and team skills, which are closely related [2].

Increases in product and system complexity coupled with the persistent time pressures of global competition mean that engineering accomplishments are increasingly made by team rather than individual efforts. This trend will continue to define how engineering endeavors are undertaken in the future. Hence the ability to work in teams is now viewed as a core competency for USA engineering graduates [3], prompting an increased emphasis on utilizing collaborative pedagogy. Accordingly, we see an increasing emphasis on utilizing student teams in engineering coursework in the USA (see e.g., [4]-[6]), in Africa [7] and globally [8].

Kenya is an interesting focus for research on teams and team skills due to the high degree of ethnic diversity, colonial era policies, the post-colonial 'Harambee' tradition, and the criticality of engineering for attainment of Kenya's national goals.

1.1. Brief Historical Perspective

The area that is now Kenya has historically been inhabited by many distinct ethnic groups with different languages and cultures, including cultures based on farming, nomadic, hunting and lake/fish food production. There are also numerous linguistic traditions, such as Bantu, Nilotic and Cushitic, with Swahili, an Arabic-Bantu mixed language, used to conduct trade. Colonization placed these different ethnicities into a single nation and established English as another language for communication between ethnic groups.

Kenya has opposing historical experiences that could serve to promote or restrict use of teams in general. Colonization utilized a governing strategy of 'divide and conquer,' such that some ethnic groups were favored at the expense of others as a means to engender loyalty and cooperation from favored groups. In some cases, individual 'chiefs' were vested with powers that traditionally had been vested in collaborative counsels of elders [9]. Perhaps prompted by this frequently divisive colonial experience, there has been a national emphasis since independence which is strongly rooted in collaboration, beginning with the 'Harambee' slogan expressed by first president of independent Kenya Jomo Kenyatta. Harambee literally means, 'let us pull together,' and has evolved into a national motto embodying the ideas of mutual assistance, joint effort, mutual social responsibility and community self-reliance. There some indication that this emphasis is present in Kenyan elementary school educational practices [10].

With regard to team skills, is the dominant influence in the education of Kenyan engineers more divisive-colonial or collaborative-harambee in nature? Does the harambee influence lead to the natural development and utilization of teams in engineering programs, or have the divisive elements of the colonial experience and the emphasis on the individual in the traditional British educational system made teamwork and collaboration difficult to achieve? How, if at all, are team activities practiced and team skills reinforced in the university education of Kenyan Engineers?

2. Method

This research was proposed as part of a teaching/research Fulbright visit to Kenya. Conducting research in Kenya by a foreign national is a formal and highly controlled endeavor. Permission and substantial fees are required by the government, who then supplied letters of introduction to local education officers. Letters from the Dean of the College of Engineering at the host institution (Kenyatta University) were then sent to the Engineering Deans at other Kenyan Universities requesting identification of appropriate engineering faculty to participate in the study. After this initial identification, communication directly with potential interviewees finally resulted in one or two interviews (seven in total) and sight visits to the five main engineering institutions in Kenya: University of Nairobi; Kenyatta University; Jomo Kenyatta University of Agriculture and Technology; Moi University; and Egerton University. Interviews were semi structured and lasted approximately 45 minutes.

Respondents represented different engineering disciplines including Agricultural Engineering, Chemical Engineering, Civil Engineering, Geomatic Engineering, and Mechanical Engineering. All respondents received bachelors degrees from Kenyan institutions. Graduate degrees were from a mix of European (French & English), Japanese, and African (Kenyan & Tanzanian) Universities. There was a wide range of experience of the respondents, from faculty in their 3rd year of teaching to almost 20 years of teaching experience. Non academic work experience ranged from none to 2.5 years, though all had a minimum of 2 months 'attachment' (internship) as part of their undergraduate education, with some having 6 or 8 months attachments split among multiple government ministries and/or private companies.

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3. Results

Kenyan engineering faculty were asked questions about their experiences with teams as students, as faculty, and as employees.

All interviewees recalled doing undergraduate school work in teams as part of their undergraduate education. This was often the result of equipment or processes that required multiple participants, or due to limited resources, for example in conducting a laboratory. Half the respondents reported that they always got individual grades for their individual reports associated with these collaborations, while half reported that at least once, some of their grade was given to the entire group, typically as a result of a group presentation. Team tasks ranged from gear box design, to research of crop processing methods, to surveying.

A majority of respondents reported that during their undergraduate education no training was provided for how to work as a team, with team membership most often assigned based on roster names, and student teams being instructed to, “Go and sort yourselves out.” One respondent reported that students attended a seminar on “Working as a team,” which was taught by business-human resources faculty.

As faculty, half the respondents indicated that current students receive team training. One school had just started, but training was not in a class taught by the respondent and he did not know any details about the training. Two respondents reported that their engineering students took a management class or seminar taught by faculty or graduate students, including how to manage people and projects and how to work as a team. One respondent indicated that students “Were not taught teamwork as a subject (in lectures) but we always encourage, ‘If you do not know what to do, work as a team.’” Half the respondents said that student teams receive a single team grade.

Both as students and now as faculty all of the respondents indicated that students were not involved in evaluation of team members.

Results were mixed when interviewees were asked about the ability of their students to work in teams. Responses ranged from, “No, they are lacking in team skills,” to “They work well together.” One respondent stated that some worked well together while others did not, and multiple respondents indicated that assigning work to teams meant that “A few lazy students would hide in the group (not do their share of the work), especially when there is a group grade.” This is not surprising given that there is no peer evaluation.

3.1. Work Experience

In spite of limited work experience outside of academia, half of the respondents reported working in a team, while one reported being supervisor of a team. Asked to reflect on these team experiences and remember a ‘worst performer’ and what made that person the worst, respondents mentioned teammates who either did not attend or were late to team meetings. One respondent spoke of a member who declared himself the team leader and started issuing orders to others. When similarly asked to reflect on a successful team ‘best performer,’ respondents identified individuals that were ‘leading by example,’ ‘meeting deadlines,’ and ‘relating well to others from all levels.’

No respondents report receiving team training as part of their professional work experience. Two stated that they were self-taught and acquired their team skills through experiences working on teams. All respondents stated that team skills were valuable in the workplace, and that it would be beneficial for engineering students to acquire team skills as part of their education. Some thought such topics should be formally incorporated into engineering curriculum, especially for final (senior) projects that are performed in teams. Some interviewees thought that team skills should be taught by other departments with expertise, and would only be successful in creating team skills if the students were receptive. Others mentioned that trainings exist, e.g., from the Kenya Institute of Management, but that such training was prohibitively expensive for both students and faculty, and generally only available to highest level managers.

3.2. Identification of Team Skills

When asked what 'non technical skills are needed for engineers to work well in teams,' respondents identified the following:

Communication
Time management
Project Management
Personal/People skills
Know how to manage the process
Work well with others
Importance of teamwork
Understanding each other
Tolerance
Know how to be a team player
Discipline/Work Ethic
Listening
Willing to accept role

4. Discussion

The team experiences and resultant team skills of Kenyan engineering graduates appear to be largely ad hoc and primarily experiential. This is problematic for a number of reasons including non-uniformity of graduates' skills, missed opportunities for knowledge acquisition and practice, and the repercussions of early failed team experiences. It is worth noting that this set of circumstances is similar to the state of engineering education in the USA prior to the emphasis on team skills engendered by ABET circa 2000.

Of the faculty interviewed, one described team training integrated into the engineering course offerings, but was unsure if this had been implemented yet or which course/faculty were involved. Those that mentioned some training available to their students from business/human resources were similarly unable to describe what specific topics were taught. When students are put into teams and told to 'sort themselves out,' learning takes place by trial and error if at all. Porter reports that the lesson students are most likely to take away from the experience is that they 'do not like to work in teams' rather than 'how to perform well in teams [11].' The trial and error method also means that, depending on what trials are experienced and what errors are made, the learning by graduates is likely to differ greatly from team to team, so the competencies of graduates will also vary greatly.

The identification of 'non-technical skills needed for engineers to work well in teams' results seem to identify both skills (that which can be learned in a relatively short time) and traits (attitudes that may be easily understood but may take a much longer time to be internalized) that are important for high team performance. This result is similar to those found in interviews with engineering supervisors in the USA [12]. Note that the wording of the question is concerned with 'non-technical skills needed to work in teams,' and interviewees responded with multiple forms of communication skills ('communication,' 'understanding each other' and 'listening') as key competencies. This also coincides with results from an earlier study [13], where USA practitioners were asked about non-technical skills needed for working in teams, and identified numerous forms of communication as the most important skills needed.

Team and other non-technical skills are becoming more critical for engineers in today's professional environment. Specifically team skills, which became a formal part of ABET's accreditation criteria in 2000, have been recognized and pursued by engineering faculties worldwide. However this pursuit has not been uniform. Borrego et al. report on publications concerning engineering teams [14], and find that over their study period 45% and 32% of the publications originate from North America and Europe respectively, while 4% originate from Africa, with 3 out of the 4 of the African publications originating from South Africa and none from Kenya.

It is worth noting that, similar to ABET, the Engineering Council of South Africa in Exit-level Outcome 8: Individual, team and multidisciplinary working, (ECSA Revison 4, South African Engineering Accreditation Board), requires graduates from accredited programs to, "Demonstrate competence to work effectively as an individual, in teams and in multidisciplinary environments" [15].

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In contrast, the Engineers Board of Kenya states that,

> "Graduating Engineers are expected to have several desirable attributes that may be expressed in terms of technical and non-technical competencies…..while the practice of engineering is the recognition and formulation of a problem and its solution including the key non-technical skills such as communication, team work, professional and ethical attitude which skills may not be sufficiently addressed within the University setting." [16]

This same article calls for much closer linkages between industry and University engineering programs so that graduates will be prepared with the competencies desired by industry. While there is recognition that there is a need for team skill competencies, there also appears to be a belief that these skills are not able to be sufficiently addressed within the University setting.

5. Conclusion

Engineering students in Kenya are required to work in teams in various courses for labs, practicals, problem solving, research, projects and presentations. While there is general agreement among faculty that team skills should be taught somewhere in the curriculum, the most common practice is to assign students to work in teams and instruct them to 'sort themselves out.'

There are different opinions as to who should provide instruction on team skills, with some believing that lack of expertise of engineering faculty in team skills means that others, such as management faculty, would be better suited to provide such instruction. Others feel that the engineering faculty expertise and experience should be formalized and presented to students as standard procedure rather than as ad hoc counseling as needs arise.

Since team activities/assignments for engineering students are already an integral part of engineering education in Kenya, providing instruction in basic communication and team skills could be accomplished with relatively little disruption to current curriculum and pedagogy. While all Kenyan engineering faculty should not be expected to expend extraordinary effort to become experts in team skills, the opportunity should not be missed to at least begin a discussion and then teach some basic team skills and practices such as evaluation of team members by team members, basic communication skills, and identification of team roles and processes. With targeted training for instructors of introductory and senior project courses, students could be assured of multiple opportunities for exposure to and performance of current best practices. Sources to consult to begin this education process of Kenyan include the BESTEAMS materials [17] and those recommended by Oakley, et. al. [18].

Without external pressure, from industry or from an accrediting body, there is likely to be little progress in formalizing the team skill acquisition process. However this pressure is not likely to emerge in the current environment where the stated belief of the Kenyan entity chartered with accreditation (Engineers Board of Kenya) is that such non-technical skills are to be imparted beyond the University setting via internships [19]. This provides little to no incentive for University engineering programs to investigate and acquire team skill competencies which can then be imbedded in the education of their graduates in a meaningful and uniform way.

Additionally, the relationship between the Engineers Board of Kenya (EBK), Kenyan Universities and Kenyan engineering graduates is somewhat contentious at present, with the EBK reported as recently suspending a majority of the engineering programs in Kenya in 2014 due to quality concerns, and a majority of those graduates eligible for registration remaining unregistered, with less than 1 in 4 of trained engineers currently registered [20]. This battle regarding eligibility of University programs and graduates is ongoing, and earlier in 2012 Kenyan courts directed the Engineers Registration Board to "… invite applications from any person eligible to be considered under Section 11(1)(b) of the Engineers Registration Act and graduating with an engineering degree from …any Kenyan public university for consideration free of any charge. Further, the registration body according to the court ruling will have to pay KES 200,000…" [21]. These circumstances have created a degree of animosity between the EBK and Universities and graduates that will make cooperation difficult to achieve in the near future.

The small numbers of interviewees coupled with the fact that potential interviewees were identified by their deans means that our results may not be representative of Kenyan Engineering faculty at large. However, the fact that the interviewees were selected by their deans could mean that even if their views and beliefs are not aligned with the prevailing view of the faculty, those views are in alignment with the vision that academic leaders have for their institutions.

6. Acknowledgements

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Virtualization of laboratory education in network security engineering

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Abstract

In this paper we discuss the benefits of virtualization of network security education environments in university level information security education. We approach the topic with regard to student learning experience, teaching staff workload, learning environment engineering, and facility use. Virtualization technologies have advanced significantly in recent years, making the switch to virtual environments possible. This paradigm shift from physical computer laboratories to virtual learning environments has gained momentum also in higher education, where large lab rooms full of computers are still an everyday reality for students. With virtualization, these computer classrooms can be repurposed as multifunctional facilities. Practical benefits for virtualization include better use of facilities, cutting costs and providing added value to both students and the faculty. Our goal is to take this emerging transformation to its logical conclusion with a fully virtualized network security education environment, with a separate network infrastructure from production networks. This environment is designed to allow students to use their own devices when doing lab exercises, with support to most popular operating systems, making it possible to arrange lab sessions in a regular classroom, or anywhere a suitable Internet connection is available.

Keywords: *Network Security, Virtualization, Learning Environment Engineering, Information Security*

1. Introduction

Hands-on experience in network security is a key aspect of security-oriented communication network engineering studies [1]. Students must be able to study network environments and to achieve this learning goal, a laboratory with sufficient equipment for different network engineering tasks and exercises is necessary. Such laboratories take up a lot of physical space and require a significant amount of equipment, such as computers, network switches, wireless routers and physical network cables, to be able to facilitate well-rounded exercises. The developments in virtualization have made it possible to manage complex systems of virtualized computers, and the application of virtualization to computer network engineering education has already been explored [2], with encouraging results.

Lab sessions requiring no oversight can be time and location independent, only requiring administrator intervention in error situations, facilitating more open and flexible learning experiences for students. Different network environments are easy to simulate, instead of having to physically rewire Ethernet network cables, switches and routers. Reconfiguration and installation of classroom computers is also very straightforward with virtual machines, compared to physical computers. Experiences with using virtual environments for education have been overwhelmingly positive at our department, for both students and teachers. We can realize significant savings in expenses combined with more dynamic teaching environments, making this a very appealing approach to arranging laboratory exercises for students, staff and faculty.

In this paper we present our experiences with virtual environments in university level network security lab education. We discuss the requirements for a network security lab, and outline our design for an environment which enables instructors to teach laboratory sessions without a dedicated computer classroom by leveraging students' own devices, such as laptops, tablets and even smartphones. We outline the requirements for such an environment, and discuss its positive and negative aspects with regard to student learning experience, education environment engineering and technology, and also consider financial implications.

This paper is structured as follows. In Section 2 we will briefly discuss what it means to shift from a physical network environment to a virtual environment. In Section 3 we give our take on designing a lab environment for information security purposes. In Section 4 we analyze the different aspects of our design, and how it will affect education goals and outcomes for students. Finally, in Section 5 we conclude the paper with notes on future development directions and research directions.

2. The shift from traditional to virtual lab environments

Our experience with virtualization of laboratory education started with the transformation of our industry partner-provided network security learning environment from host-based to virtual environment, where a significant part of resources run on virtual machines [3]. In this environment, a classroom of interconnected host computers and physical network infrastructure is still required, binding resources in computers and premises. If we consider an average computer classroom, most of the space is taken by physical equipment, leaving very little space for other purposes. This has been one of the main motivators behind our redesign of the lab, but other aspects of lab teaching will also significantly benefit from redesign. Requirements for a network security laboratory can vary significantly depending upon topic areas and education goals. Next we will examine the requirements for a modern lab environment, describe our current setup and how it matches to the previously presented specification, and finally outline the future lab environment and the solutions behind it.

2.1. Requirements for a network security laboratory environment

Network infrastructure: A lab should provide means for students to configure, design and implement different network infrastructures, and to actually test their work and receive feedback on their performance. Computer networking can be a difficult topic for students, who may not be used to conceptualizing complex network structures. Actual design and administration of a nontrivial computer network is not an easy task, and while this is not the goal of network security education, those responsible for planning and implementing network security features and also investigating possible failures should have a good grasp on networking, above the usual level of connecting few devices to a home router and calling it a day. Physical network hardware makes this process more concrete, but virtual networks can be so much more versatile that using virtual networking gives significant benefits for education.

Server infrastructure: Server hardware is required for running the virtual environment. Before OS virtualization was as common as it is now, laboratory environments required a lot of hardware, as all hosts computers, servers, network switches and access points had to be physically present and properly configured. Computers require power and space, and thus a dedicated space is required for a teaching laboratory. With virtualization, we can run complex environments, with several servers and host computers in different networks, on a single computer, eliminating a lot of space requirements.

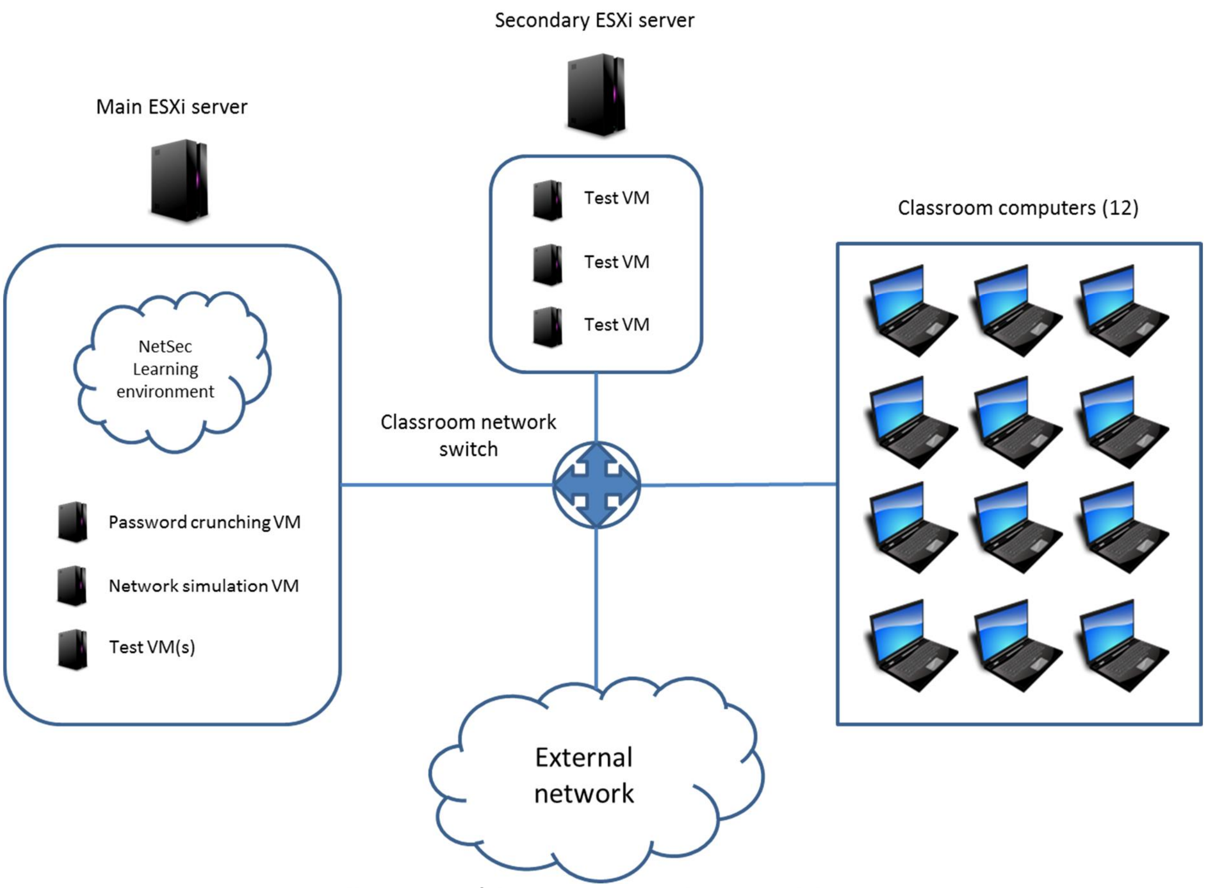

Figure 1. Illustration of the current network security lab environment

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Availability: A learning environment should be available to the students as often as possible. While contact teaching is important, repeatedly doing exercises and experimenting on the students' own time is also a very important part in internalizing network security concepts.

Resources and platform support: A learning environment for network security should support as many different OSs and configurations as possible. In real network environments there are hosts with different OSs and configurations, and a lab environment should be able to reflect this by providing easy support for changing configurations on hosts, and adding and removing hosts from the environment. The environment should have sufficient resources, so that it can provide at least adequate performance in a teaching situation. Some extra resources, whether they are hardware or software, should be reserved for situations where unforeseen events strain the environment.

2.2. Current lab environment

The current layout of our security lab can be seen in Figure 1. We have a dedicated classroom for our security lab, which contains 12 classroom computers for students to use during exercises, and two servers responsible for running virtual machines that make up the actual learning environment. They are interconnected by a gigabit Ethernet network set up in the classroom, with an optional connection to the university network and Internet, if necessary. We also have the option of setting up a wireless network in the classroom for research and education purposes, such as WLAN security audit and testing. The main server runs an instance of the network security learning environment, which is used on a course on firewalls and IPS technologies, directed at master's students in network security. Both main and secondary servers also host additional virtual machines, used as computational resources for research purposes.

3. Analysis of requirements for virtualization of laboratory environments

The first thing to take into account when beginning the process of migrating from physical to virtual environments is to define the requirements for the new environment, and what kind of tasks can be assigned to the lab. In our case, we need to provide sufficient resources for a firewall and IPS laboratory environment with over 50 virtual machines in one instance, and preferably the ability to run more than one instance of the environment simultaneously. Additionally, a penetration testing environment with several virtual machines should be running constantly, with access from outside the university network made possible to students. Our way of approaching this problem is to define *learning environments*, of which we run virtual *instances* in our servers. This makes it possible for many students to be working in the same environment at the same time, increasing the capacity of a limited environment.

3.1. "Bring Your Own Device" policies and virtualization

Bring Your Own Device (BYOD) is an IT policy that has been advocated as a way to save costs in IT and provide users a better user experience. Instead of forcing everyone to use a single pre-chosen IT solution, BYOD aims to reduce organizational IT hardware costs by allowing users to use their own preferred devices, whatever they may be, for work. This is also sometimes referred to as *Bring Your Own Technology* (BYOT), which reflects the inclusion of both hardware and software [4], as it is with modern mobile devices with different software ecosystems and hardware. BYOD (or BYOT) gives users the interface and software they are familiar with, the capability to use the device they choose with all the benefits, and translate these into productivity in a work environment. For more discussion on BYOD, its motivations, benefits and challenges, see for example [4] [5].

In an environment as strictly characterized by software choices as network security lab education, this may first seem to be a hard goal to achieve, and some of the known downsides of BYOD such as incompatibility with some infrastructure choices cannot be avoided. But if we wish to reach our goal of doing away with the dedicated lab room for network security, we must provide means for the students to bring their own devices and use them in doing the lab exercises. This way, the requirements for fixed infrastructure are reduced, as the university does not have to keep and maintain a full classroom of computers for the students to interact with the teaching environment. On the contrary, in a best case scenario, we can eliminate the computer classroom completely.

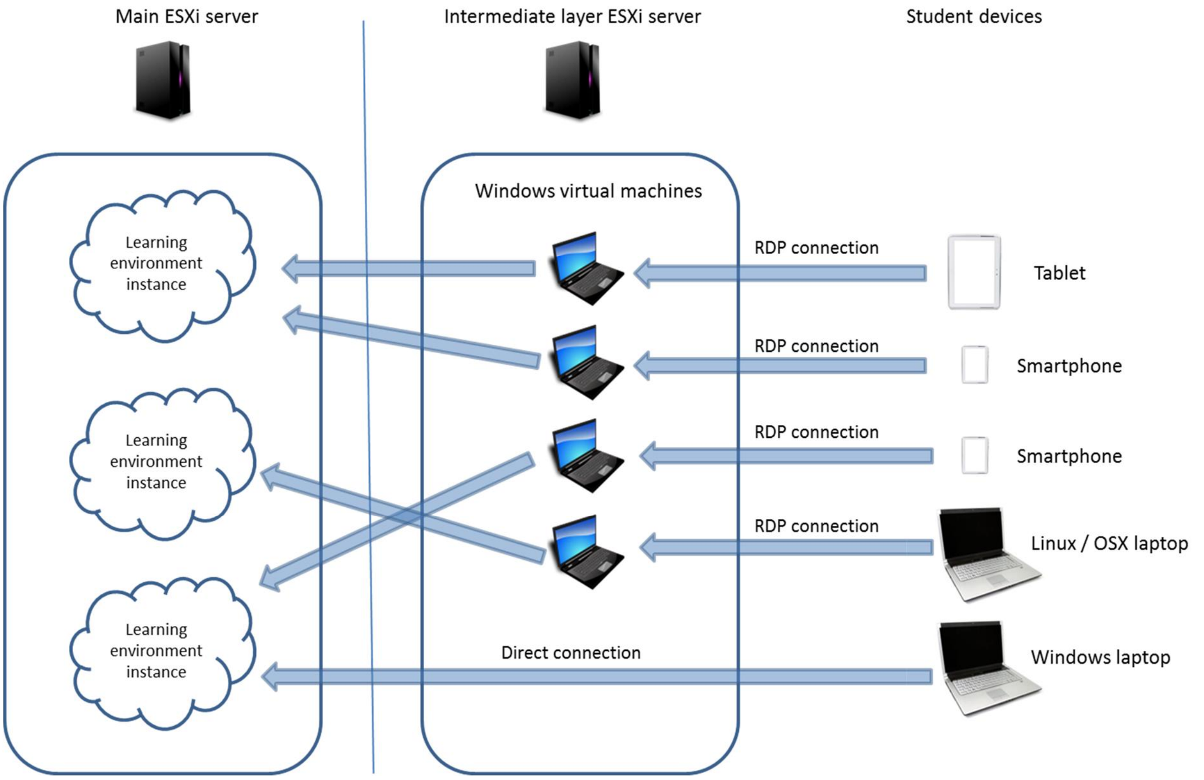

Figure 2. Connecting student devices to learning environments, either directly or with RDP and Windows virtual machines.

Now we can summarize our approach to BYOD security education. We use Windows virtual machines as a translation layer between incompatible devices and lab infrastructure, guaranteeing the opportunity to participate in the labs with your own device with almost any possible hardware combination. Windows Remote Desktop Protocol (RDP) is leveraged for this purpose. RDP makes it possible to remotely control a computer from a device capable of running an RDP client. As RDP has such a wide support across all operating systems and platforms, and, so far, only Windows is capable of running all necessary software for the laboratory sessions, this makes the combination a natural choice. In Figure 3 we demonstrate this concept with an Android Nexus 5 phone being used to control the lab environment, in such a manner as described in Figure 2.

Figure 3. Connecting to and managing a virtual machine in the learning environment on a smartphone.

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3.2. Hypervisor selection

An important part of the design process is choosing the hypervisor upon which everything will be built. A hypervisor is, simply put, an operating system that is capable of running instances of other operating systems all at the same time. It is the core element of virtualization, and several choices for a hypervisor exist. Virtualization can be achieved with several different solutions, both open source and commercial software. A hypervisor can run on top of a running OS, or on top of “bare metal”, i.e. there is no other OS between the physical hardware and the hypervisor. In this paper, we focus on a bare metal hypervisor approach, where we use VMWare vSphere [6] as the platform of choice. The same can be achieved with open source solutions such as XenServer [7], with configuration, setup and administration being different, but the basic principle remains the same, and both could easily be used to construct such an environment. In our case the choice was driven by administrator familiarity with the system.

3.3. Hardware selection

We will build our new lab environment using hardware from our previous lab environment, so that we can reuse as much of the previous hardware as possible. We must take into account the fact that the cycle for computer hardware is somewhere around five years, and while obsolete hardware can be reused for some other purpose, for the heavy lifting part we will need to source new hardware.

The current lab consists of 12 Core 2 Duo E8400 computers with 4 GB of memory, a setup consistent with high-end hardware 5 years ago. One E8400 computer has been outfitted with 16 GB of RAM, and it was used as a server for a limited version of the virtual environment. As the main server the lab has an Intel i7-3770 with 32 GB of memory and a SSD hard drive, and this server has been responsible for running the virtual environment thus far. For network connections we have two 24-port gigabit Ethernet switches, several smaller switches, and wireless access points and adapters for adding a wireless network to the environment.

To future-proof our environment for a reasonable time frame, we are considering for the main environment a server with two Intel Xeon E5-2630 processors and 128 GB of memory. We can reuse the old main server and some of the older student computers as servers for the intermediate layer and other auxiliary tasks, giving us more resources for dealing with unforeseen situations.

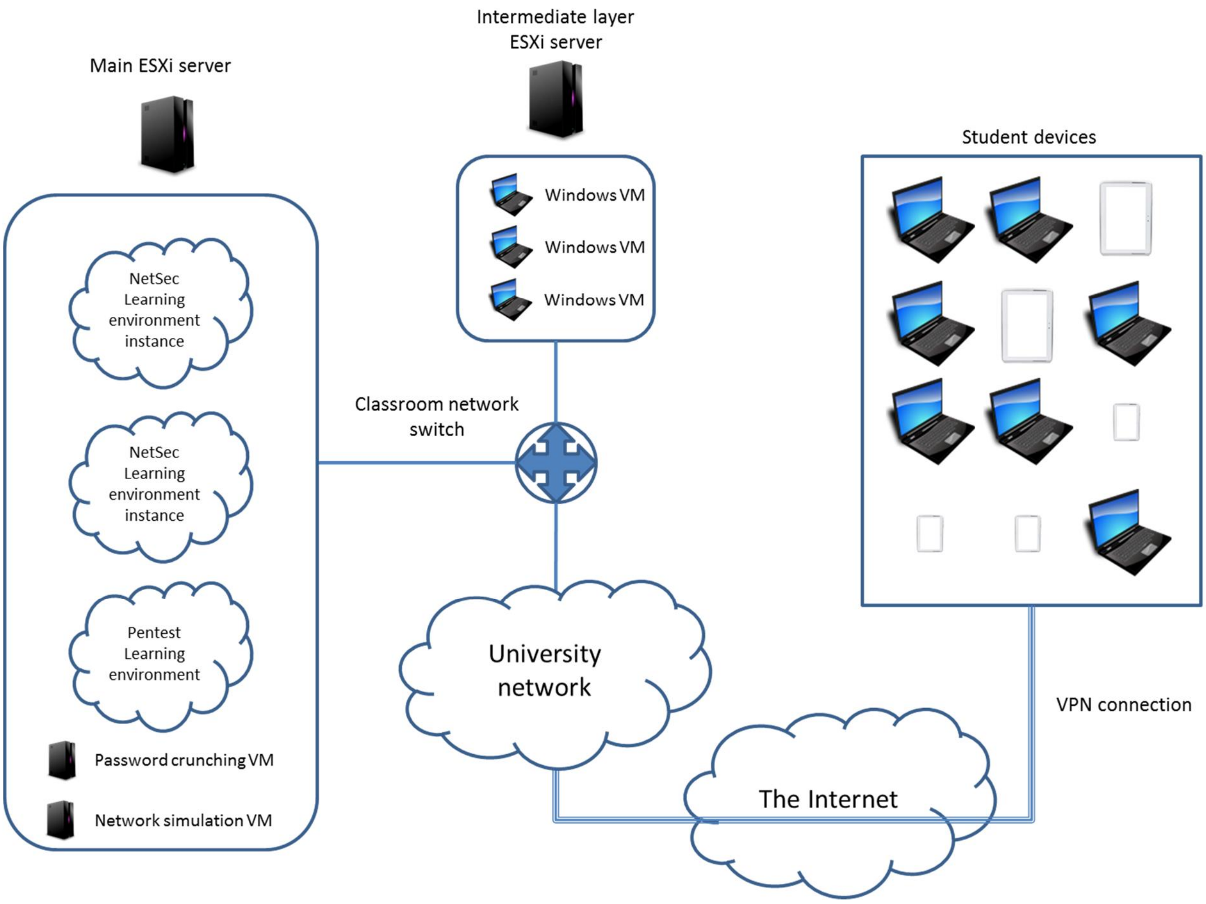

Figure 4. Diagram of the new network security learning environment.

3.4. Description of the new environment

The new education environment is run completely on virtual machines. The only physical components are the main servers and a network switch. They can be placed anywhere within university premises, but it is recommended that they are accessible in case of a failure or for maintenance purposes. The student devices use a Virtual Private Network (VPN) [8] connection to the university network to gain access to the main server. VPN is a standard technology used for securing connections over insecure networks and providing confidentiality and connectivity to users. One of its most common implementations is granting access to a restricted network through the organization network perimeter firewall to remote users. In our case we use the standard VPN solution for remote access provided by the university IT administration to all students and staff.

After this first step, the students can now access the environment. If they require a Windows host for interacting with some components, they can control a Windows VM remotely by using Remote Desktop Protocol (RDP), for which a client is easily available for any operating system and platform. Over the RDP connection the students are essentially controlling a classroom PC, and can use it for interacting with the learning environment.

The learning environments themselves are modular pieces in this architecture. We can modify, add and remove environment instances as we please, as long as we make sure that the environments are reachable from outside the main server. This is managed through configuring the virtual network adapters in the environment to connect to the correct physical network adapter.

4. Effects of virtualization

The virtualization approach applied to laboratory exercises traditionally done with dedicated hardware and a classroom does also carry some inherent risks and challenges, which we identify and discuss their impact and relevance here.

4.1. Student learning experience

Actually understanding the topology and layout of a network, the location and relations of different host on a virtual network seems to be, in our experience, very difficult for a nontrivial amount of students. When we are working with abstract concepts such as virtual machines, it is often hard for a student to understand what computer they are trying to manage at a certain time, or how traffic is routed and networks are connected in virtual environments, as there are no physical, tangible references for them to use as a reference. When dealing with a physical environment, the instructor can always point out a single computer and say “´This computer here runs that server you are now connecting to, and that device there is running the firewall you are connecting through.” Also network connections are easy to visualize when students can physically follow the network cables from host to switch to another host, if necessary.

In our experience, this is significantly harder to conceptualize for students working with a virtual environment. Students are more often configuring wrong virtual machines, or fail to understand how a network is connected, when asked to debug a non-working configuration. As we can see, losing touch with actual physical hardware can be a problem for some students. While the truth is that most people do not have to deal with networks more complex than a simple home network, students in the information security and network security field should be at least familiar if not comfortable with administering non-trivial computer networks with more than one or two hosts, whether they are made of physical or virtual components.

The User Interface (UI) on a touch-based device differs significantly from an UI designed to be used with a keyboard and a mouse. This can be a problem for some students who use a touch UI to interact with the virtual machines, causing problems with typing on an on screen keyboard, a smaller display, and so on. These kinds of challenges limit the usability of the environment for those who do not have a traditional laptop.

Virtualization also makes it possible to integrate lab exercises with regular classroom teaching. Combining lectures and lab sessions normally requires arranging the lecture in a dedicated computer classroom, where we can provide a computer for every student with the necessary software, but with the ubiquity of sufficiently powerful devices, we can take advantage of this by embracing BYOD. Now that every student can use their own device to interact with the training environment during a regular lecture, we can integrate exercises into lectures more efficiently. This makes it possible, for example, to use a 30 minute segment of a lecture to talk about firewall rule table creation, and use a 15 minute segment for students to do a related hands-on lab exercise where the students create their own rule tables in the learning environment. With virtualization, this can be done with the student’s own devices, in the classroom, without a dedicated computer lab.

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Student-instructor interaction is a vital part of successful lab sessions, and it first may seem that transitioning to virtual environments decreases the amount of contact teaching, but it does not have to be so. This will only be an issue with lab exercises that students can do any time they wish, and even then there are several methods for interaction between students and faculty. Options range from on-call hours at the office, Skype / other video conferencing meetings with students, message boards, e-mail messages, to instant messaging software and Internet Relay Chat (IRC) chat rooms, all depending on circumstance. These means do not supersede or make obsolete contact teaching, but rather make it possible for at least some kind of interaction in lab exercises with independent schedules.

4.2. Education environment engineering

Virtual machines are much more flexible and usable from a lab engineer point of view. Simply the ability to have snapshots of a virtual machine state, having more than one snapshot available, and being able to switch between snapshots makes it possible to maintain several instances of an education environment concurrently. If we are working with normal computers, when a student performs a lab sessions, manually reversing all changes that have been made can be prohibitively time-consuming. Non-persistent virtual machines offer the possibility of having computers that can be used for a lab session, and they can be reverted to their original state for the next student simply by restarting them, as no changes made to the system are actually written on disk. After several years of experience on administering both virtual machines and physical hosts, we can with reasonable confidence say that administration and environment engineering is significantly more streamlined and less taxing in a virtual environment. Actual instructor workload supervising students can be difficult to measure between these scenarios, but our estimation is that they are approximately equal. Virtual machines give the opportunity for the instructor to remotely assume control of a host for troubleshooting purposes without moving around in the classroom, but otherwise the workloads can be estimated to be similar.

4.3. Technical considerations

We must also consider the requirements this setup poses for the network used by the students to connect to the environment. If we have 20-30 students all connecting via the same WLAN access point, this will definitely cause traffic congestion in the network. This would be a typical situation for a standard classroom setting, so steps must be taken to ensure that we have sufficient bandwidth available for all students. Some mitigating factors can be students who use their own ISP connections on their own devices, and dedicated WLAN access points configured to provide access for students. Network connection quality and availability is essential for this virtualization scenario to work, so we should assign sufficient resources to ensuring that the network will not become the bottleneck.

Of course some students will not be able to participate with their own devices due to technical difficulties, malfunction, not having a suitable device in the first place, or forgetting to bring one to a session. This problem is easy to manage with a small number of laptop computers that can be temporarily assigned to students who would otherwise not be able to participate in a session.

Perhaps the most salient threat scenario for this kind of environment is hardware failure. As it is with any hardware, equipment failure can result in critical data loss, possibly erasing all progress made by students in a session. Especially when we are working with a main server, any fault will probably cause catastrophic failure. A distinct benefit for standalone hardware for all hosts is that the risk of hardware failure is distributed, leading to a lower probability of data loss in case of failure. This risk can be mitigated with redundancy in server hardware, but only to a certain degree. We must eventually accept some level of risk in such an environment regardless, and with good industry standard practices these risks can be mitigated sufficiently.

4.4. Financial considerations

While our foremost goal is not to consider financial incentives, we must note that depending on circumstances, this can also be considered as a driver for virtualization. For departments that have to spend money on facilities, reducing the amount of real estate on lease can bring cost savings. In our case, these savings are in the order of tens of thousands of euros, but this naturally depends on facility costs that can and do vary between locations. Also, maintenance of a computer classroom, replacing outdated and malfunctioning hardware, also takes resources, both in the form of money and time spent on administering the classroom computers.

5. Conclusion

In this paper we described our experiences with virtual lab environments for network security education, and outlined our next step for providing better network security lab education for our students. By making the laboratory infrastructure platform agnostic by using virtual machines as a translation layer, we can provide a similar experience in each client device class to all students, regardless of the platform that each student has chosen for themselves. This provides means to offer lab education not only independent from a classroom, but also makes it possible to students to do lab exercises on any platform, any time they choose. The benefits are clear both for students and faculty. The students get a more flexible approach to exercises and the possibility to use their own preferred devices in education, and the faculty gets better education potential, increased throughput for student exercises, and possible financial savings in reduced premises and classroom computer maintenance. The risks of the virtualization approach have been identified to be mostly dependent on hardware failure, and with sufficient backups and good practices in place, we can conclude that the benefits of virtualization in network security laboratory education far surpass the risks.

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Defining and measuring key expertise areas in information security for engineering students

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Abstract

In this paper we discuss what kind of and what level of requirements on information security knowledge the emerging information society poses for its citizens. By defining key topic areas of interest and mapping out essential skill sets and knowledge areas in information security for engineering students in relation to these requirements, we start to assemble a framework which can be used for developing information security education. First, we divide the field of information security into subcategories and map them to different learning profiles, based on different levels of required competence. With the help of an online learning environment, we analyze preliminary results on measuring students' expertise and development in lower expertise levels in the context of an entry-level course on information society and cyber security, where we piloted the framework that we have developed. We discuss the practical arrangements of three online exams with the goal of efficiently measuring student knowledge on information security, and present preliminary data on learning results using the first version of this framework.

Keywords: *Security Knowledge, Information Security, Engineering Education*

1. Introduction

As we as a society move further into a true information society, it is just not the security professionals who have to be cognizant of information security issues. Students of other engineering disciplines, other professionals, and also the average layman also need to be aware of information security issues. What everyone needs to learn is very much dependent on their chosen study area and professional profile, but even now everyone needs to learn at least a limited subset of information security knowledge, and this development will continue.

In this paper we start forming a framework for efficient teaching of information security to higher education engineering students, with the goal of eventually extending this framework further into other disciplines and levels of education. Our goal is both to eventually educate engineers with information security focus, and students in other disciplines with a strong grasp of essential information security concepts, and the ability to adapt and use this knowledge in practice. Therefore it becomes vital to correctly define what key areas of expertise in information security are for all key demographics, and having a clear vision on what to teach to and how to approach each group.

This paper is structured as follows. In Section 2 we begin with definitions on information security and information society, and discuss why they are important concepts to teach to students. In Section 3 we define three different learning profiles for engineering students, and discuss what they should contain. In Section 4 we divide the field of information security into four thematic areas, and present our view on what aspects they should contain. Then we map the learning profiles to thematic areas, fleshing out the framework for security education. In Section 5 we report our experiences on using the framework in teaching a first-year IT engineering course on information security and information society. We leverage an online learning platform for conducting exams designed based on the framework to assess student learning performance. We report our findings and discussion about future work on the topic. In Section 6 we finally finish the paper with our conclusions.

2. Information security and the challenges of information society

Information security is, by a broad definition, the discipline that is concerned with securing and protecting information systems against internal and external threats. Actual definitions range from "[…] protecting information and information systems from unauthorized access, use, disclosure, disruption, modification, or destruction […]" [1] to describing information security as a parasitic order machine [2]. A universally accepted general definition seems to be elusive for information security, and provokes discussion [3].

When we consider information security as a field of study, we can immediately acknowledge its complexity and wide scope. To give a short introduction on different areas in information security, we can point out that topics can range from cryptographic protocols [4] to semiconductor physics [5] to computer network security [6] to theoretical computer science [7] to software engineering [8] to policy management [9][10] and social engineering [11][12]. Just the number of different aspects information security has suggests that teaching all of these subject matters to every engineering student in higher education is practically impossible, let alone impractical.

Our society has arguably already transformed itself into an information society, where a significant part of important society functions are performed, run on, or dependent on computers and the Internet. To be able to function effectively and safely in our modern society you must have internalized among other topic areas certain basic concepts of information security, with associated knowledge and behavior models. On a general layman level we can immediately define some common ground rules, ones that are in public discussion all the time, such as not to respond to phishing emails or never to give their password over the phone to someone, or understanding what your personal information is, how it is protected and should be protected by businesses and the government. Other important areas of knowledge are what it means to have a secure connection to a web server, what are the realistic capabilities of possible malicious attackers with regard to different services, and yourself, or what can be gathered from your data, and metadata, and so on.

Therefore we must be able to solve a very difficult equation: we need to simplify complex issues sufficiently to teach them to a wide audience, but also at the same time we must provide cutting edge education for those who are interested in learning the state of the art in information security. Combine this with limited resources, and we must begin to choose our education profiles very carefully, and target our efforts to the correct audiences. We can easily argue that everyone should have at least a basic grasp of information security concepts, but in this paper we will mainly focus on higher education engineering students in IT related fields, as they are on the forefront of information society as consumers, creators, maintainers and protectors.

While it is out of the scope of this paper to explore this any further, we must additionally remark that the question of core competence in information security is also a relevant question for all other fields of education, and by extension, all of society. Many basic functions in our society have been transformed: online banking, online shopping, social networks, and even voting in elections can be done online in some instances. These are all basic functions that everyone needs access to, and everyone needs to be able to use, and also perceive the possible risks and threats that these new services have. This means that everyone needs to have a certain understanding of the underlying system, and this brings us to information security and information security education, and the importance of recognizing that what is now considered to be in the realm of IT professionals will eventually creep into other aspects of life, and eventually be a part of everyone's basic knowledge [13].

3. Learning profiles and demographics for information security knowledge

Definition of different student demographics is a key step in the process of improving information security education by targeting the correct information to the correct demographic group. This targets education precisely to the students that need it. In this paper we will focus on engineering students, with a particular emphasis on IT and IT security engineering students. Existing literature is far from homogenous on this matter. Studies focusing on information security awareness, education and training often target company employees, separating them based on titles, responsibility areas or employees and contractors [14], or diversify the responders based on age and level of education [15], or focus on university staff and policy makers instead of students, and with the goal of mapping out vulnerabilities in the security environment rather than assessing student learning development [16]. Previous studies are often made with a more general student population and targeting less specific security knowledge [17], or are directed towards student ethics rather than in-depth student security knowledge [18] [19].

As we have no obvious usable prior demographic division to use as a model, and we are targeting a specific subgroup of students, we have to define our own demographic divisions. We begin by identifying three groups within engineering students, with associated learning profiles.

Non-IT engineering student: Engineering student in a non-IT related field, such as mechanical engineering or civil engineering. These fields may have a wide range of requirements for IT literacy and security knowledge. For most parts we can estimate that the basic minimum requirements are that they can handle themselves in a modern office environment without hazarding the security of their employer, and similarly they are capable of understanding and mitigating information security risks in their personal lives, in a similar manner to an average person. Some disciplines may require more advanced IT literacy and use capability than non-engineering students, with associated requirements for security.

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IT engineering student: Engineering student in an IT field, such as computer engineering, embedded systems engineering or communication systems engineering, requires in-depth knowledge on one or two IT topics, and a basic understanding on most areas, from algorithms to databases to semiconductor operating principles. Information security knowledge required can vary between actual profiles, but for the most part they should be able to understand the topics from the previous profile.

IT engineering student with security focus: An IT security professional whose main task is to analyze, develop, implement and evaluate information security related things. Emphasis in this profile is focused on security topics, in addition to the learning profile from IT engineering student.

The relation between these profiles is inclusive. IT engineering students should incorporate non-IT engineering student learning profile contents to their own, with some limitations. Similarly, a security focused engineering student should have for the most part the same learning profile as an IT engineering student, but with some additional requirements in security knowledge, and perhaps some relaxations in other areas. Next we will present a thematic division of the field of information security, and map the previously presented profiles to these thematic areas.

4. Thematic areas in information security

As we have already established, information security is a field that encompasses many disciplines. When we approach the question of what to teach to students with different learning profiles, we must first divide the field into manageable sets of compatible concepts and technologies. Taxonomies on information security are for the most part more focused on modelling things on a more granular level [20] [21] [22]. When we consider the 12 main themes and 43 sub-themes defined in [20], where the focus is on quantifying directions of research in information security, we consider this approach to be too granular for defining manageable knowledge areas for security education. Instead, in this paper we use a division of thematic areas in [22] as a basis for our classification. In it, the authors define three loose knowledge groups: v*ulnerabilities, threats, attacks*; *security protocols, mechanisms, policies* and *controls, countermeasures.* We had already identified a similar set of thematic areas on our own, giving support to this division of concepts as very intuitive. After additional drafting and analysis, we decided to add the thematic area of *data security and information criticality* to fully flesh out our modified choices for thematic areas, as presented in detail below.

Vulnerabilities, threats, attacks: This thematic area contains the concepts of vulnerable software, hardware and wetware (i.e. people), and the threats and methods that leverage and use these vulnerabilities. The concepts of malicious software, different malware types, and their capabilities are also included here. Knowledge about attackers and their goals and motivations, different attack types (active or passive) and softer methods such as social engineering is also an important part in understanding vulnerabilities and threats, so they are included in this thematic area.

Security protocols, mechanisms, policies: In this thematic area we have placed more abstract concepts and systems related to information and security system complexity and security policy definition. The idea of the Confidentiality-Integrity-Availability triad and its extensions are also included. Other topics include risk analysis and risk management, threat recognition and mitigation, cyber security and cyber warfare, critical infrastructure awareness, and legal frameworks,

Controls, countermeasures: This thematic area contains the most traditional information security concepts, as they are the most salient for advanced users, and also some of the most complex. They include firewalls, intrusion prevention and detection, cryptography, password security, RFID and NFC technologies, and in general, technological solutions that can be used in implementing information security.

Data security and information criticality: Data is a significant driver, whether it is business or private. Understanding different kinds of data (location data, medical data, financial data, personally identifiable or sensitive data, etc.) and its value and applications is critical for many professions and fields of work. Management of data is brought into personal frame of reference with our personal data. Data storage and especially cloud storage are important concepts that by themselves justified a separate thematic area. Network surveillance and privacy, metadata and metadata analysis are also grouped in this thematic area.

4.1. Learning profile mapping with thematic areas

Next we map the previously presented learning profiles into our thematic areas, and define – in broad terms – what are the requirements for each profile in each thematic area. For easier referencing, from now on we refer to

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the learning profiles as Levels 1, 2 and 3, as the like we already noted earlier, the profiles are inclusive when we move forward. Generally on level 1 in all thematic areas, the requirement is to understand the basics, level 2 requires deeper understanding of the background and the capability to apply learned knowledge to practice, and level 3 requires, in addition to the previous levels, the capability to design, analyze and/or implement and manage entities in the thematic areas. Competence on level 1 can generally be gauged with an online exam designed accordingly, but it gets harder as we move further in the framework, as the focus moves from knowledge and understanding to behavior and applying knowledge to practice.

Table 1. Mapping of knowledge areas to education profiles

	Non-IT Engineer (Level 1)	**IT engineer (Level 2)**	**IT security engineer (Level 3)**
Vulnerabilities, Threats, Attacks	Aware of existence and capable of identifying when encountered.	Understands fundamental operating principles, and how they work.	Capable of analysis and/or reproduction, has deeper understanding of operating principles.
Controls, Countermeasures	Understands basic concepts, functions, limitations and threats. Knows what assets they protect.	Understands underlying principles, capable of applying existing controls and countermeasures in practice.	Capable of managing, analyzing, or designing new countermeasures and security controls.
Security protocols, Mechanisms, Policies	Understands scope and purpose. Knows how to evaluate situations and comply with policy. Understands risk management thinking.	Capable of applying processes and policies to own work.	Capable of evaluating and designing policies and processes. Can monitor and supervise enforcement of policies. Understands people's normal and abnormal differences.
Data security, Information criticality	Understands concept of critical data, importance of securing it, and where it is located. Separation and securing of personal and work data.	Able to protect critical data. Capable of applying principles of data protection to own work, deeper understanding of technical ramifications and information value.	Capable of evaluating soundness of data protection and managing mission critical data. Ability to design new data protection methods.

When we examine the thematic areas more closely, we can postulate that the requirements on level 1 will be the "new normal" for information security knowledge for the average person in the future. The advance of the information society coupled with the permeation of computers in all aspects of our lives will certainly act as a driver for information security, and place pressure on everyone to adapt secure practices in their everyday lives. This requirement creep will make something now in the realm of IT professionals to everyday knowledge in the not-so-distant future.

4.2. Critical knowledge areas in information security

Now we will approach the question of what topics in information security can be considered to be of critical importance. Based on the mapping presented in Table 1, we define critical knowledge for an engineering student to be at the very least what is covered in the non-IT engineer column, or level 1, in all categories. What we have considered to be critical knowledge within the thematic areas can be summarized as follows.

Controls, countermeasures: network security concepts such as firewalls, antivirus systems, and methods for securing communications, specifically cryptography and its basic principles.

Vulnerabilities, threats, attacks: fundamental knowledge on malware, how they function and what they target, different vulnerabilities in software and systems and what kind of attacks can be targeted against them.

Security protocols, mechanisms, policies: security policy fundamentals, meaning of security awareness to overall security, security as a mindset.

Data security, information criticality: importance of data in information society, fundamentals of data protection.

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5. Assessing information security knowledge in students

So far in this paper we have defined information security thematic areas and learning profiles for students. To test our framework, we have used it in first year education of IT engineering students, attempting to target our target demographics with the right level of information. Next, we examine the results of a course designed to teach information security concepts and knowledge to a class composed of students with a varying background. For now, the course is directed at first year IT engineering and computer science students, with a small percentage of students from other disciplines doing a minor subject in IT. The main method for assessing student performance and learning in the thematic areas is an online exam that is administered at the same time to all students using an online education environment. The exam is not the only graded part of the course, contributing about half of the grade on the course, a large group assignment being the other contributing factor.

5.1. Online education environment

The ViLLE platform [23][24] is an online learning and collaboration platform initially developed for programming education, but has been extended to a full-fledged online learning platform, capable of supporting automatic checking of programming questions, several different types of assignments, and, most importantly for us, a flexible way to do online exams for a course. We decided to use ViLLE for the course because it provided us a flexible platform that supports automatic checking of exams, even for more complex exam types than multiple choice exams, and because of the integrated statistics and data extraction tools, giving us good tools for gathering and mining data on student performance.

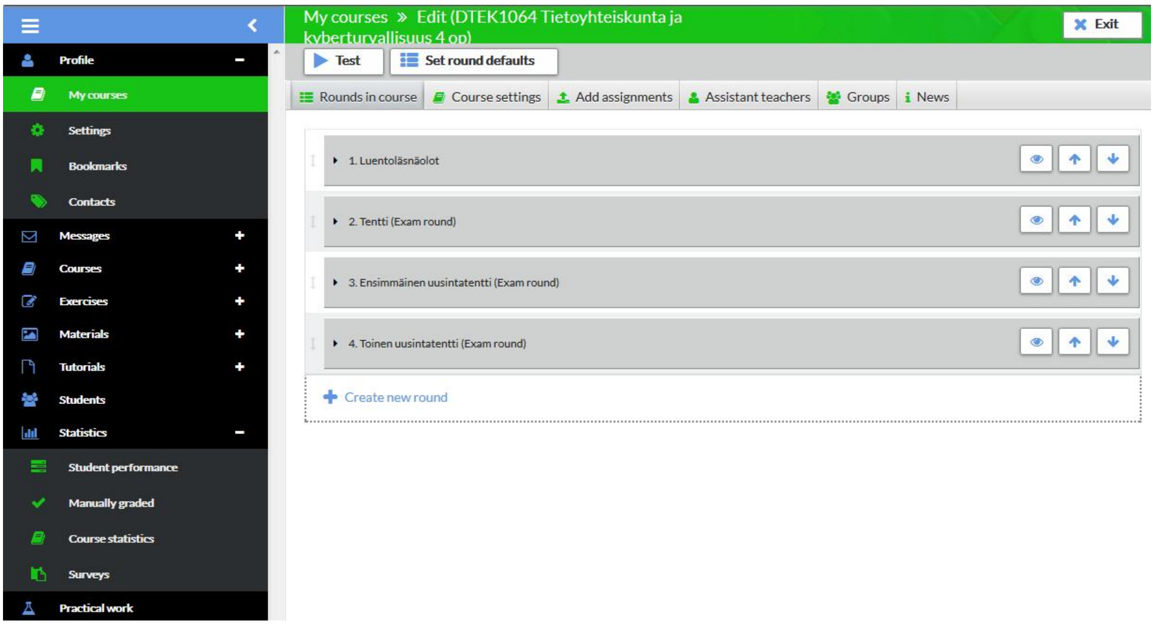

Figure 1. Viewing the course in ViLLE, with lecture attendance assignment and separate course exams

5.2. Measuring learning outcomes

The exam we use to gauge student learning performance and knowledge on subject is implemented on the ViLLE platform as an online test, available to all students on the course at the same time. The exam is location independent, so students can do the exam wherever they want, as long as they have an Internet connection available. The exam is naturally open book, as students will have access to all lecture materials and the Internet, so any advantage students may have from doing the exam in groups is mitigated. The exam is structured according to our framework, so we have made a set of questions for each thematic area, divided into smaller randomized sets that can be assigned individually to students, making each instance of the exam random. The questions themselves are designed to measure knowledge and understanding on level 1 of our framework, because the scope of the course is in first year students. The correct answer gives one point, incorrect answer gives one negative point, and selecting *don't know* gives zero points, with the purpose of conditioning students not to resort to guessing in matters of information security.

Our goal is to expand the use of this framework into education in advanced level courses, where we would have to engineer methods for assessing knowledge, understanding and behavior of students in more demanding levels of competence. This would give us better control on the students' overall learning process from introductory to advanced level courses.

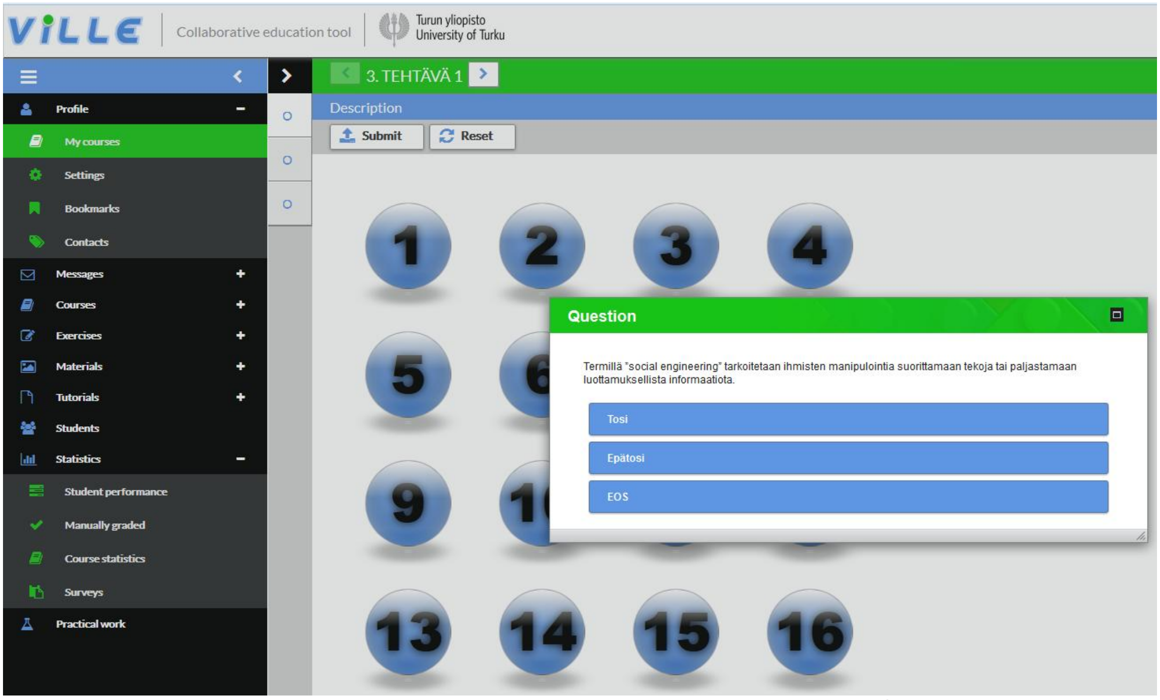

Figure 2. Answering a multiple choice question in the exam with the options *true*, *false*, and *don't know*. The question itself is about the definition of social engineering.

Data from the exam questions shows us, that the most difficult thematic area was controls and countermeasures, and the area that had consistently better results was vulnerabilities, threats and attacks, as seen in Figure 3. The other areas fell in between, but with similar percentages in the 80%-90% range. Our goal for the students was to have them score 90% or more overall, and we achieved this only in one category. The goal was set so high because the students had all materials available during the exam, and also had access to the Internet, which corresponds to the normal situation the students have when facing a problem: they Google it. The questions were designed to be not that hard and we focused on basic knowledge in thematic areas, justifying setting the target to be as high as 90%. From Figure 4 we can see, that out of all questions in vulnerabilities, threats and attacks, more than 75% were answered correctly >90% of the time, signifying that nearly all students had a good understanding of the area, contrasted by only about 33% in security protocols, mechanisms and policies. The amount of data in each category is yet too small to yield robust results, but these preliminary results serve as a motivator for refining our framework. Especially the data security and information criticality area has very limited data, and those results should be considered as tentative at best, but this can be attributed to its late emergence after the first analysis on preliminary results from the exam. One definite key future work aspect is strengthening this thematic area.

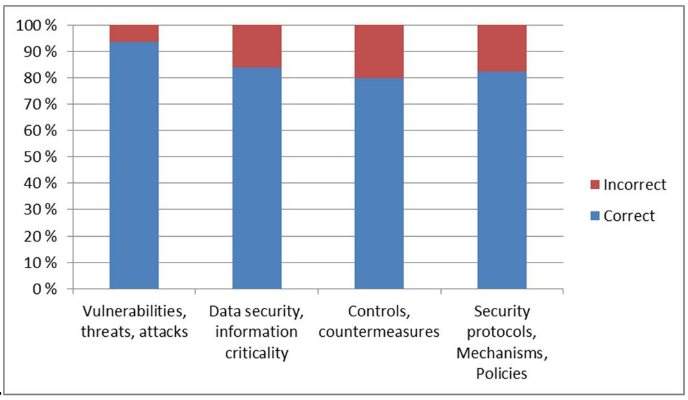

Figure 3. Percentage of correct / incorrect answers for each thematic area.

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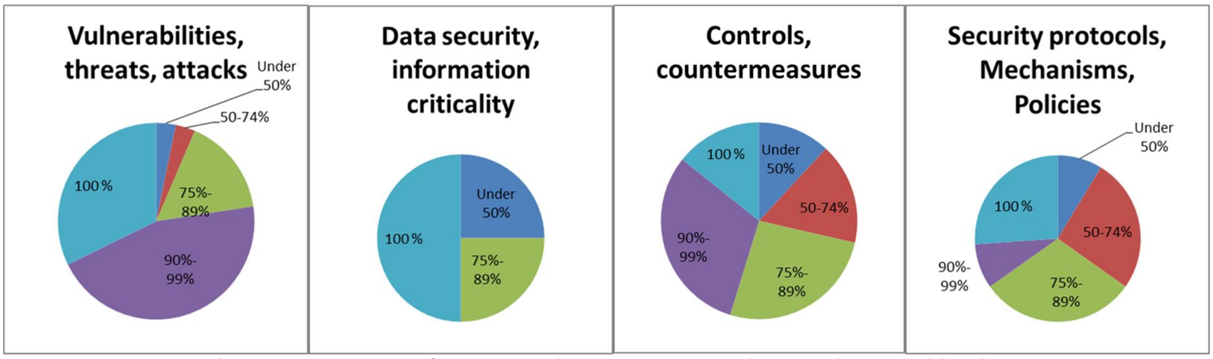

Figure 4. Relative proportions of questions that were answered correctly, sorted by thematic area.

The results also reflect the fact, that vulnerabilities and data security are categories that students have had more contact with through the group assignment that forced students to ponder on these issues on their own. Also, based on the data in Figure 4, we assume that students yet lack the technical and mathematical framework to process concepts like cryptography and security policies efficiently. We could perhaps facilitate this by directing group work tasks in these directions, making the students focus on these topics even in simplified cases. While we do not yet have sufficient data on this, we hypothesize that data security and information criticality will emerge as a theme which is taken more seriously by older students. This is due both because they are further in their studies and understand the role of data better, and because younger people are more comfortable with sharing their data in general.

5.3. Discussion and future work

Our framework for teaching information security concepts has provided us with a clear method for creating sets of exam questions that are able to measure student performance within our thematic areas. It can be used for preliminary level testing, and making sure that all relevant aspects of information security for each target learning profile are taken into account.

One salient feature we noticed was that after critically examining our chosen exam questions, we found that all questions except one (roughly 99%) were focused on measuring student's knowledge on the topic, instead on their perception on how to behave in a secure context in challenging situations. Some arguably behavioral aspects were present, but they were approached from a knowledge viewpoint. While behavior is hard to measure or gauge in exams of this format, one key future development is developing a test which would also incorporate behavioral issues, while being implemented on an online learning platform.

The long-term goal of this framework is to expand it to cover behavioral aspects, and expand the learning profiles outside engineering education, aiming for a generalizable model of security education that can be adapted to different levels of education, with readily made questions in a suitable reference frame and a flexible platform for practical implementation. The first level of security knowledge does not include several important aspects of information security knowledge, and a major future endeavor is to expand the question sets to cover the thematic areas in more detail. Possible expansions include more in-depth technical topics, legal requirements, standards and security frameworks, which all are in the domain of the IT security engineer, in contrast to the general knowledge aimed for non-IT engineers.

6. Conclusion

In this paper we discuss the problem of information security education, the complexity of the field, and the necessity of information security education due to the advent of the information society and the requirements it places on everyone, from the layman to the expert. We approached this by proposing a framework for information security education. First we described different learning profiles for engineering students combined with division of information security into thematic areas and mapping them together to form an initial version of the framework. We provide our experiences on using an online learning platform in practical implementation of this framework in engineering education, and we show that our framework is suitable for testing student knowledge on critical expertise areas in information security based on a pilot implementation of the framework on an introductory level course on information security. More comprehensive analysis is pending after we get more data from further iterations.

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Management of parallel change request processing

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Abstract

Change requests are common part of the software product lifecycle. They can be initiated by end users because of legal changes, business process change or improvement as well as system errors, and by developers or system designers. If the support team should resolve requests sequentially, there would occur a lag time while waiting for the end users' feedback, therefore the support team members are working on the multiple requests in the same time. As the number of requests executed in parallel grows, the time requested to switch between the tasks becomes significant.

Keywords: *information systems, ERP, Change request management*.

1. Change Requests

Contemporary software product lifecycle consists of the blueprint/planning, development, testing, implementation and go-live and support phase. In order to reach the project milestones and meet the go-live deadlines, some of the project goals may be omitted or postponed for later development.

With this in mind, it is obvious that the software product is subject to changes. When the need for software change is detected by end users, it is common practice that they express their wish to the team that is responsible for software product support and maintenance. Such demand for software product modification is referred to as change request (CR).

Main drivers of software changes are: blueprint redefinition, legal requirements and business process changes. Started by end users, requested change is evaluated by support team members. Depending on the nature of change, the team that will solve the change request is composed, and the effort needed is assessed. Although often under or overestimated [1], this rough estimation is the basis for support team activity planning. According to [2], some of the main reasons for effort estimation errors are „unrealistic over-optimism“, „complexity of application underestimated“, „overlooked tasks“, „lack of user input“ and „incomplete requirements and specifications“, therefore those aspects should be carefully considered in order to minimize estimation errors.

During the whole CR processing cycle, extensive communication between support team and end users representative is present. Especially in multinational environments, such communication can be time-consuming because of different working hours, time zones and business priorities.

In the testing phase, the end users have no knowledge about the parts of the software product that were subject to change. Therefore, the full set of tests is the only way to prove that change is efficient, and without remedy to other parts of the product which have no obvious (from the end-user point of view) connection to the requested change.

Support team members are specialized for various areas, either by their formal education or by experience. Managing such a team must take into the consideration the demand level for certain specializations in the planning period in order to avoid the bottlenecks that occur because of expert shortage, which was reported as a number 1 shortcoming in [3].

As the cost of task switching in software development has been a recognized problem for many years [4], the biggest improvement by means of time efficiency and resource usage can be achieved by reducing the context and task switching times, and improving the communication between the parties involved by preparing the required data in advance, so they can be used when needed.

2. Processing Model

2.1. Stages in change request processing

Usually, the end users express the CR demand. In this phase it is common that the business background driving the change is described, as well as how the process is presently done, and what is the expected process in the future.

When the support team receives the CR, it is confirmed that the request is fully understood. If the CR description is insufficient, further communication is conducted until more detailed specification is reached. Support team must then evaluate request for feasibility, interference with other processes and compliance with the global software development strategy.

The next step is effort estimation. Prerequisite for this step is that CR must be well defined, and all the needed specializations are defined. Special care must be taken if the interconnection with other systems is involved. In that case, the impact and possible changes within other systems must be taken into consideration.

In the development stage, technical obstacles are avoided to meet the expressed (n.b. not the expected!) final system behaviour. End users must keep in mind that nothing is assumed, and the system will at best function just as literally described in CR. According to the support unit organization, developers are responsible just for basic function testing, and very often not even that.

It is up to the end users to test the overall system behaviour and approve that it meets the expectations. Testing with productive data is the quickest way to check how the system will perform in usual cases, but it should not be the only test conducted, and it surely isn't the best one. The system behaviour must be defined within all the data inputs that can appear. So it is strongly advised to create the test battery which will cover all possible combinations of data inputs, as well as the system response in these cases. User should sign-off CR as finished only after the full battery of tests is successfully conducted.

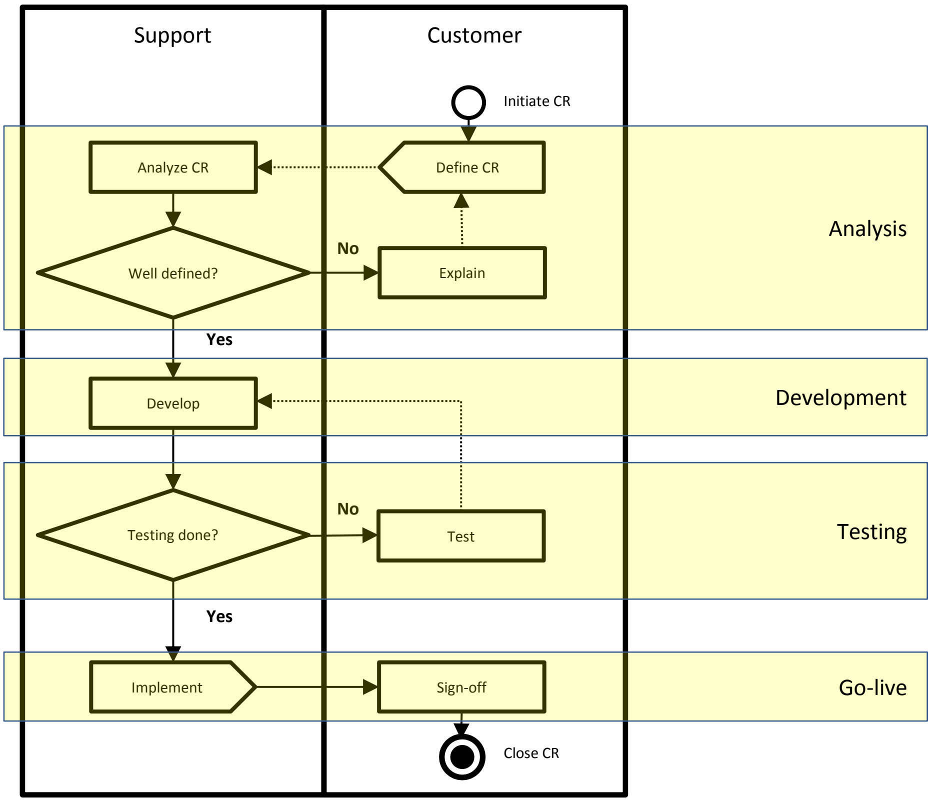

Figure 1. CR processing model

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2.2. Example

An example was constructed from the consolidated actual data obtained from several organizations operating in various European countries. All of them share the same basic CR processing model. Support teams are usually geographically separated from the end users, and most of the communication is done by video/tele conferencing and e-mails.

Data analysis shows clear indication that change request processing without proper parallelization is far from optimal.

2.2.1. Data analysis

The following table presents descriptive statistics related to duration time (in days) which is obtained as a difference between the date when a customer request has been solved and a date when the request has been started. The number of days is expressed as a length of time (in days) started Jan 1st 1900.
It can be clearly seen that there is a significant amount of zeros which indicates that some of the requests have been solved the same day. For that reason and the fact that the highest value is 1124, the median is taken as a measure of central tendency.

The median duration is 120 days which indicates that the difference between the solved date and the started date is 120. The average number of days to resolve the request is approximately 143 days.

The coefficient of variation, (the relative dispersion), CV = 104% which is large showing that data values vary around the mean.

Table 1. Duration of execution

Duration	
Mean	143,066
Standard Error	8,606
Median	120
Mode	0
Standard Deviation	149,563
Sample Variance	22369,019
Kurtosis	8,699
Skewness	2,312
Range	1124
Minimum	0
Maximum	1124
Sum	43206
Count	302

The classification of the previous values regarding the request time is shown in the histogram on Figure 2. It can be seen that the most of the time the requests have been resolved during the time period from 3 to 5 days. The distribution of the time is as shown.

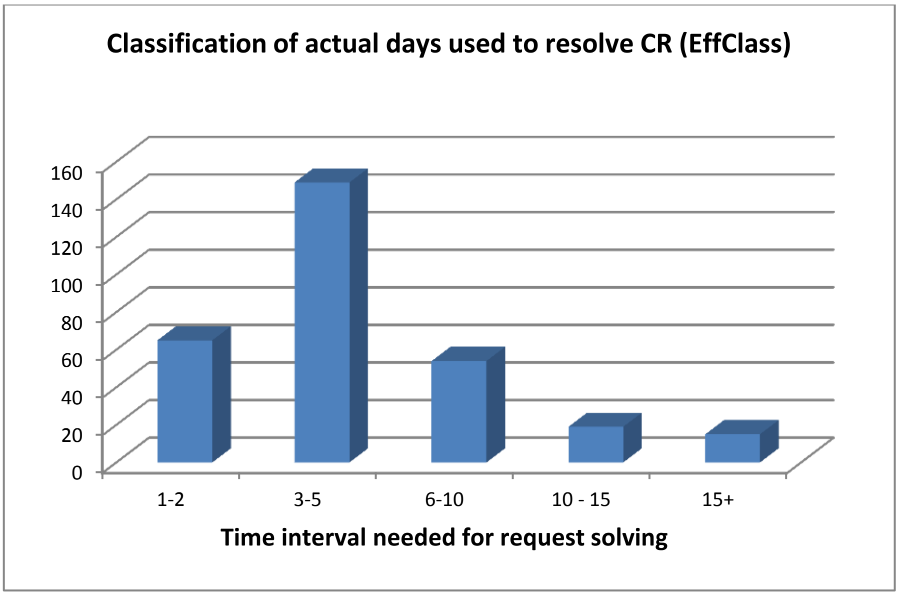

Figure 2. Effort classification

Paired two sample t- test is performed. As expected, the test indicated the significance (the p value is extremely small) which shows that the difference between the duration time (explained previously) and the duration of man – days (effort time) which presents the real time spent for resolving the problem is not zero. Obviously, the null hypothesis which stated that there is no difference between the duration time and effort time is rejected at all significance level.

Table 2. t-Test: Paired Two Sample for Means

	Duration	*Effort*
Mean	143,066	4,272
Variance	22369,019	27,919
Observations	302	302
Pearson Correlation	0,264	
Hypothesized Mean Difference	0	
df	301	
t Stat	16,269	
P(T<=t) one-tail	1,93 E-43	
t Critical one-tail	1,6499	
P(T<=t) two-tail	**3,86423E-43**	
t Critical two-tail	1,968	

2.2.2. Challenge

With the mean of 4,27 days needed to complete the task and 143 days to wait for it, it is reasonable to ask whether it can be done better, and what parameters can be modified to achieve that.

3. Improvements

In distributed international environments, delay in communication between team members and end users is significant, and often requires context switching, meaning that from the time the support team requires testing from the end users until the time the tests are done, substantial amount of time passes. In that time, support team deals with other requests, and when the test results come back, the team members have to get acquainted with the CR facts again, just to get back into CR context again.

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Most obvious results are expected in the environments with frequent and inefficient communication, by reducing the number of sessions, and preparing the required inputs in advance. Communication sessions can also be grouped by participants, meaning that same participants can communicate the topics from several different CR's.

Although, as stated in [5] it is not known "how many percent of the researchers are really working on testing", further improvements are achievable in the testing area, by preparing the test batteries as early as possible, even as the part of initial CR. If the test cases are prepared upfront, and the testing time is scheduled and fixed, the time required from support team to get back in context is much smaller.

3.1. Parallelization

The goals of parallel solving of multiple CRs are capacity increase (more CRs can be solved with existing resources) and solution acceleration (CRs can be solved quicker). Also, according to [6] "Features of parallel development projects can also be merged into a single future system, which may yield a net saving of 50% in development activity."

Regardless of the size of the support team involved in CR solving, it is evident that some waiting time or lag is present. To get the most use of available resources, several CRs are processed in parallel.

As a first step for parallel execution, every stage must be divided into atomic tasks, which would be the smallest reasonable task which can be executed independently. To define what is reasonably small for the atomic task, we must decompose the steps to the tasks which have no interaction with other tasks during the execution. Interaction should be limited to the time prior the execution (inputs) and after it (results). Similar tasks are to be recognized so they can be grouped together for execution by the same resource, which will lower the task switching overhead.

Parallelization can be achieved with the respect to team member (one person doing several tasks), and between team members (several experts on the same task).

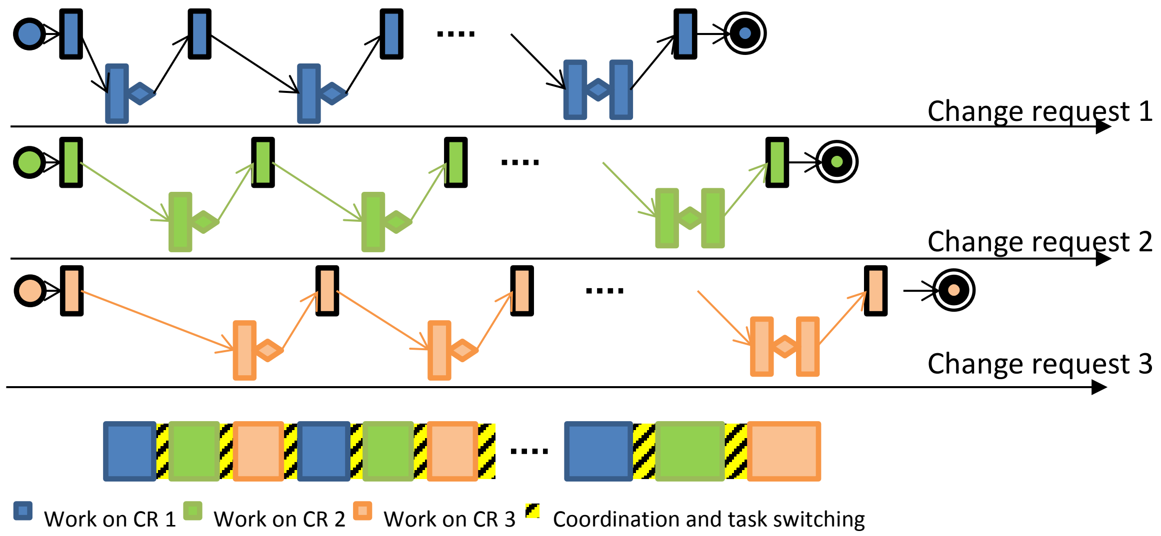

Figure 3: Parallelization

3.1.1. Interdependence of processes

Main prerequisite for parallel execution of tasks is concurrency (the ability of the task to be executed in parallel). They must not be ordered (depend of the result of the not yet executed tasks), the shared resource (expert) they require must not be used by other task, and they must not be in conflict with another task (to prevent other task to be executed, or to be prevented from execution by some other task).

In the early days, the common bottlenecks for software development were the hardware resources, but in today's world of clouds and virtualization, it is less likely that this would be a showstopper. More likely, today it will be a human expert.

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If the input parameters for any stage are results of some other stage or process, the execution of it cannot start before previous results are known, and the previous stage is finished. If specific expert resources are needed at some stage of the process, and expert resources are limited or otherwise busy, the stage cannot be executed until expert resources are free. If the requested change depends on some other system, the inputs and outputs from the other system must be defined and experts for the other system consulted before the processing can continue.

3.2. Shorten communication times.

In the next step all needed communication between team members and with end users must be defined, along with information flow and communication participants, identifying team members and end user representatives. The communication has to provide clear definition of scope and goals, all the requested input data and expected outputs, as well as obtained testing results. Prototyping is suggested in [7] to enhance the communication.

3.3. Optimize context switching

Context switching (working on the same type of task, but for different CR) is caused by waiting for the communicating partner (from the end-user side) to provide further instructions, clarifications or in most cases test results.

According to the information obtained by interviewing several members of support team we assessed mean times needed to regain focus to task in hand (Table 3). If the response from the end users is received by support team member within 1 day, it takes about 6 minutes to get back into the task context. If it is received after about one week, the time needed to refocus is estimated to 10 – 20 minutes. When the month passes between question and response, reported context switching times, depending on the task complexity, varied between 0,5 – 2 hours, averaging at 1 hour.

Table 3: Mean context switching times in relation to time lag

Time lag	Context switching time
1 day	6 minutes
1 week	15 minutes
1 month	1 hour

3.4. Optimize Task switching

After CR is prepared for processing, we can group the similar tasks from different requests and assign them to same available resource.

Task switching (changing the type of task to work on) times can be well managed inside the support team, even by the individual team members themselves.

3.5. Beware of the overhead

Parallel task execution has its price. We have to add time needed to coordinate, and switch tasks and context (overhead time) to execution time for every atomic task, for every CR in execution. Based on the data obtained from support staff interview and example presented in 2.2 we extrapolated relation between time spent to solve the task and overhead time in dependence on number of CR's executed in parallel. It can be seen on Figure 4 that with 44 CR's in execution, more that 50% of time allocated to single request is spent on overhead.

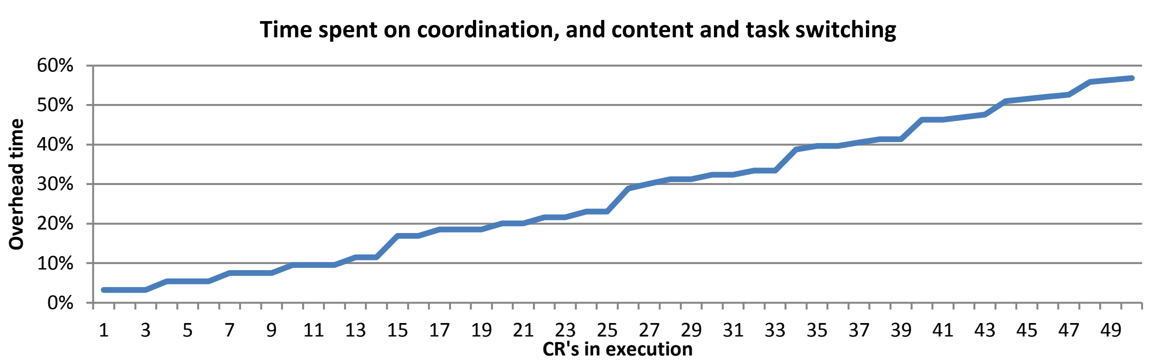

Figure 4. Overhead time as a percent of overall time in relation to number of CR's in execution

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4. Applications in education

Managing changes in the software systems has been the research topic from the early days of professional software development. Managing processes and teams that conduct such changes was rarely addressed, while we can see the need for that in the industry.

4.1. Class exercise as a "Proof of principle"

In order to improve the collaboration with industry as well as raise awareness of parallel processing advantages among students, a practical lab experiment was conducted. The results can then be presented to the industry to support or weaken the hypothesis.

4.1.1. Example from ERP course

Students were divided into two groups and presented with the set of tasks which should be completed in the following order:

a) Create vendor master data
b) Create article master data
c) Create procurement document
d) Create customer master data
e) Create sales document

Each student from the first group (A) must complete his own set of tasks (a, b, c, d and e), while the same number of cases is assigned to group B. Students from second group (B) are divided into specializations: vendor, article and customer master data specialists (tasks a, b and d), and procurement and sales document specialists (for tasks c and e). Each specialist starts his task as soon as the input data is ready. Times to complete all tasks were measured and minimum and mean values are presented in Table 4. Although the fastest individual from group A finished his task before group B, total time for group B is ~15% shorter than for group A mean.

Table 4. Times to complete exercise with vs. without task switching

Time to complete	Group A	Group B
Minimum	55 min	
Mean	68 min	58 min
Max	75 min	

5. Conclusion and further work

Introducing parallelization and reducing task and context switching in change request processing can substantially shorten execution times. Since pilot project is available from our industry contacts, it will be interesting to see if the results will be the same as in the class.
Furthermore, as a direction for future work, it will be useful to analyse the potential impact of applying some of the Agile software development methodologies and processes which are now found in the mainstream [8]. However, the question of which particular process from the Agile paradigm to adopt is still complex, reflecting the challenge of matching work style to project type and organizational culture.

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Information System as a Management and Communication Device for Scientific Research at the Moroccan University

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Abstract

In a context of E-Governance and modernization of higher education, the Moroccan University is facing new challenges, such as:
- Orientation, development and promotion of scientific research that meets the needs of the socio-economic environment and therefore affects the lives of citizens.
- Developing the culture of communication and information by ending practices that limit the dissemination of information.
Moroccan strategy for the development of higher education has focused all its projects on the use of new technologies for the management and structuring of research, and the promotion and enhancement of its activities.

To this end, the establishment of an information system for the management and communication of research in the university can organize all the research activities, structure research units on an administrative and financial sides it can also communicate its work to enhance the sharing and open a window of partnership with its socio-economic environment.

This work aims to develop an information system for management, information security and communication research in the Moroccan university. This system will allow collecting, classification, processing and disseminating information related to scientific research at the university in order to organize and structure all its activities. It will also enable all university's actors to use a digital workspace to access and share information, and therefore interact and get involved in the promotion of scientific research at the university.

Keywords: *Moroccan University, Scientific Research, Information System, Management, Communication, Information Security.*

1. Introduction

The technological revolution in the world encourages University to adopt new sharing and communication tools for meeting the needs of its socio-economic environment [1]. So it permits the growth of the economy and the sustainable development of the country [2].

A good use of these tools allows universities to manage their research by the rationalization of human and material resources and the opening of a portal collaboration with the various stakeholders involved in scientific research. So the Knowledge in real time, becomes a key factor in the success of the essential business strategy [3].

Currently the Information System "IS" is a necessary device that meets all these objectives. It is also a mean of connection to the internal and external world of the university, which contributes to the democratization of information. The logic of social development dictates the need to direct managerial attention to knowledge management [4]. This “IS” highlights the important role of information in the organization's operating processes and systematically addresses major [5]. In this case, the value of good communication and effective exchange of information are important to participate in the management and decision making [6].

In Morocco, we opted for the establishment of an "IS" at universities to have an easy access to information related to scientific research, and this through the placement of functional blocks [7].

In this context, the Moroccan universities have decided to adopt a numerical application named «SIMarech» set up by Abdelmalek Essaâdi University-Morocco, it aims to develop an initiative of an information system with the ultimate goal to support researchers and enhance their scientific activities [8].

This management tool is a successful experience for the direction of research in the Moroccan university; it manages the functions of downstream research and provides access only to the internal stakeholders of the university.

Furthermore, the present work aims to establish an information system in Moroccan universities to manage scientific research in any phase and communicate its results internally and externally.

It will take into account the particularities of the Moroccan university in a governance context places since 2009 [9]. This requires the pooling of all resources in order to overcome the lack that scientific research in the Moroccan university is suffering. So that will ensure how various organizational factors can affect scientific production [10].

To do, a number of Fars topics of scientific research will be considered. We begin with the management of the human resources and the structures of scientific research sections. In Section 4, we examine the organizational structure schedules and events related to the research. Section 5 will focus on the management of the various university partners for scientific collaboration. The section 6 is the collection and management of deliverables. Section 7 aims the organization of mode of collaboration between university and external actors of scientific research. In section 8 we will try to define the terms of the financial management of research at the university level. Section 9 puts action on the information security management by implementing an ISO 27001 repository [11] as system performance and efficiency of the information. Section 10 concludes the paper.

2. Human Resource Management:

This party of platform will focus on the collection and saving of information of all internal stakeholders of scientific research in the university. Initially they are called to identify and fill the canvas for a login and password. Once validated, these identifiers allow them to see the different sections of the application as provided.

All information gathered will allow us to provide in real-time, statistics about quality, quantity and distribution of human resources related to scientific research in the university.

This will allow proper sharing of internal resources in order to derive the maximum benefit and profitability.

3. Management of research structures

The management of this section is a responsibility of the directors of research structures.
We can find two types of information:
• Public information concerns the number of structures, their members, their research areas and even the equipment issued to each structure;
• Private information represents the status of the work of these structures. This information can only be accessed by those involved and becomes public after their completion.

The various research structures will be listed in detail allowing to have an idea about the human and material resources set up by the university in any objective pooling and profitability.

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4. Managing Search events schedules

There are three types of schedules:
- Events organized by scientific research structures in order to make known their work and encourage the involvement of socio-economic partners;
- Events organized by the university to promote scientific research;
- Schedules of specific training for PhD students, managed by the doctoral studies centers (C.E.Doc).

This section aims to present an annual calendar of all scientific events. The organizing parties (structure, university, C.E.Doc) are required to provide the necessary information about the event they plan to organize by following a framework dedicated to each. This will optimize the use of logistical facilities (date, room, lecture hall, program ...), avoid overlapping and communicate about the event.

5. Management of partnership agreements

The different types of university's partnership established allows its resources (student or staff) to have more opportunities to discover new modes of education, to mix with the external environment and also to exchange good research practices.

The particularity of the Moroccan university permit that partnership agreements can be proposed either by the rectorate of the university or by teachers.

In both cases, the actor will give all the details on this proposal (partner, context, purpose, fundamental provisions ...) according to a canvas to follow. The university's research committee has the responsibility to validate the proposal or request it for modification. Once it's done, we will proceed with the signing of the agreement.

In an updated list, the platform will provide information with the details of agreements and their progress reports.

Thus information system will organize all partnership stages from the proposed agreement, through the study and follow-up to this collaboration.

6. Deliverables Management: thesis, research papers, patents…

The deliverables of university research structures is a criteria of scientific production, which it is based to evaluate research at the university.

The information system as a concept of management and communication can organize this part of research; it will allow each user entitled to access to provide partial or complete information about its research work either part of thesis, summary of patent or a paper.

This information must be published on this topic so that, all the actors of research structures are aware of the progress of work.

Information becomes available after its validation, its communication will allow for any interaction between actors.

7. Share Management and collaboration with the socio-economic environment

This section will be an open window to the socio-economic partners to have an idea about all the activities of scientific research at the university and benefit from its expertise in detecting areas for potential matches.

This collaboration can take many forms:

- Training to corporate profits

- Projects as part of research and development

- Training for university's students

- All other services

The applicant provides in a canvas all informations about his application, it returns to the University Research Committee which will be responsible to study, validate and route it to the appropriate unit.

As the collaborative work ahead, research structure should systematically provide information about the progress of this partnership.

8. Financial management of the search

University's research structures receive annual budget allocated according to specific criteria: it depends on resources involved in the rate structure, rate of scientific production and radiation rate and openness to its environment.

The budget allocated to structures is divided into three parts:

• The capital budget: includes expenditures for research structure for construction and purchasing scientific equipment;

• The operating budget: includes expenditures necessary for the operation of the research structure;

• And the budget to support events and mobility: it is managed at the university rectorate and aims to support the structures' organization of events and mobility of teachers and postgraduate students as part of their project.

Research structures may receive other types of exceptional revenues from international projects in which they are partners or by providing expertise according to external applicants to the university.

The financial management of research structures by an IS, allows good use of allocated budget, it will provide them an automated and transparent monitoring of revenues and expenditures, while respecting the principle of autonomy.

The research structure will provide with a canvas all the information on its budget and its use.

However the budget of support is a subject to prior approval from the Committee on Research.

Initially only the information related to the action to be taken will be indicated in a specific canvas.

The management responsibility of the fourth type of budget, it allow to directors of research structures, so they should provide indicative information.

With this IS, we have in real-time information concerning the conduct of this section.

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To resume all interactions between the sections outlined above, this scheme bellow can explain it:

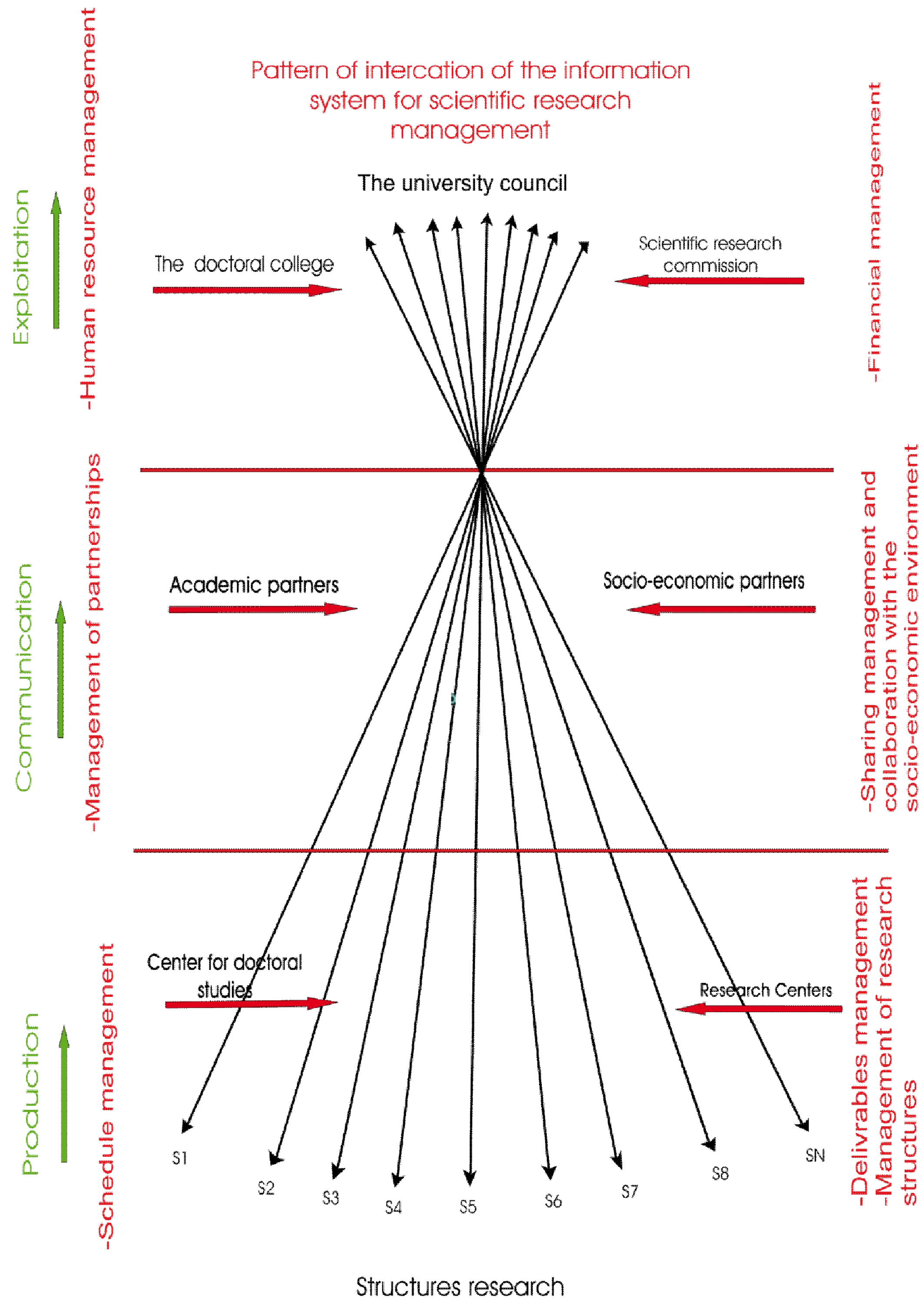

Figure 1: Synthetic scheme of interaction in the IS for management of scientific research.

SN (N=1; 2; 3…): Research Structure at university

9. Information Security Management by the implementation of ISO 27001 repository: information security management system of "ISMS"

An information system as we designed, allows us to have a variety of information, a set of data and more interactions, in short it is a real asset for the university which provides overall management of the sought after.

Therefore, it is necessary to ensure the effectiveness and performance of this information system, this can be achieved through the development of a management and security system that allows both to organize and secure the IS established.
This security management system must guarantee three objectives “ACP”:
- Availability: Access to information at the right time to authorized persons;
- Comprehensiveness: Ban to modify any stored information;
- Privacy: Prohibition on access to sensitive information to unauthorized persons.

ISO 27001 management system deployed in the Information Security " ISMS " is the approach that meets all these needs and provided a set of requirements that will facilitate the management of information including those related to data personnel, the financial data, information on future projects and even to documents submitted to intellectual property.

The overall approach to be followed in applying that standard to the IS for the management and communication of research in the university should take the following steps:

9.1. Phase Plan: Planning the process of securing IS

This phase is based on three components:

1- Analyze the information risks
2- Evaluate risks to treat them properly
3- Choose the appropriate measures to be in place.

It also relies on the real commitment of the university to set up this ISMS perimeter determine where we will apply the ISMS.

9.2. Phase Do: implementation of objectives

This phase is the heart of the norm, as it allows setting a plan to address the risks previously evaluated and organize measures to implement in practice. For this you have to go by the choice of measures to secure the IS Research, identification of indicator and staff training and daily management of the ISMS by procedures.

9.3. Phase Check: setting control means

ISMS implemented systematically must be monitored to measure its effectiveness and compliance, and therefore the IS for research s will be subject to verification tools, such as:

• Internal audits: Review previously planned involving auditors;

• Internal controls: Controls within the university to verify the application of the procedures put in place permanent;

• Sunset Reviews: Always verify that the ISMS is online with the particular environment of the university and adjust every time.

9.4. Phase Act: Implementation of action:

After establishing monitoring tools and detect malfunctions ISMS to the IS-Research, it is important to put in place: corrective actions, preventive actions and improvement actions to propose action that can improve the performance of the security of the IS-Research.

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10. Conclusion

In a governance context, the Moroccan university is called to modernize its higher education provision and scientific research by adopting a policy of automation of information that will allow its management and communication.
Taking into account that the information system is a management concept, its implementation in the organization of research can communicate about its work, attracter new partners and promote its activities.
As discussed in the paper, the sections managed by the IS are the keys to the activity of research and its most basic functions, hence the importance of protecting any information contained by the establishment of an Information Security Management System which provides diversified actions to ensure continuous improvement..

11. Acknowledgement

My thanks go to all those who supported me in making this work by offering me their time, their energy and their commitments. I present them my deep gratitude.

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Innovation

ICEE 2015

Inspiring Innovation

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Abstract

Innovation is the agent of change. It is the catalyst for continuous creation of new products, processes, services, and businesses. This paper articulates the taxonomy of inspiring students to engage in innovation journey. It provides a road map of how to awaken passion for innovation, develop and nurture mindset for innovation, overcoming barriers for innovation, understanding the thinking tools and characteristics for innovation and experiencing through the innovation journey.

Keywords: *Passion, Innovation, Design, Tools, Characteristics, Entrepreneurship*

1. Introduction

"The key to our success – as it has always been – will be to compete by developing new products, by generating new industries, by maintaining our role as the world's engine of scientific discovery and technological innovation. It's absolutely essential to our future." – President Barack Obama, November, 17, 2010.

The history of human evolution is intertwined with innovation. "Just as energy is the basis of life itself and ideas the source of innovation, so is innovation the vital spark of all human change, improvement and progress". – Theodore Levitt. From bicycles to space satellites, slide rules to super computers, telegraph to cell phone, candle to electricity, voodoo medicine to cancer cure innovation played the central role. In fact, every spheres of our well-being: food, health, medicine, transportation, communication, energy, environment, entertainment, technology and education innovation continues to be the engine of change. The future economic growth and global competitiveness is largely depending on our next generation's mindset, desire and success of innovation.

Innovation is not invention. It can be an extension of an invention. Innovation is a dynamic endeavor of finding a better way everyday whatever we are doing today. Innovation can be viewed as an iterative decision making process to transform a creative idea to practical reality for developing more effective (cost, efficiency, sustainability, design, aesthetic etc.) products, processes and services for the benefits of the people, society and the environment. According to Steve Jobs "Innovation has nothing to do with how many R&D dollars you have. When Apple came up with the Mac, IBM was spending at least 100 times more on R&D. It's not about money. It's about the people you have, how you're led, and how much you get it". The fundamental question then is how do you inspire and prepare students to engage in innovation? Inspiring innovation starts with awakening passion. Curiosity and asking questions sparks passion. Who are our role models? Why? What inspires us? What makes our heart sing? The following philosophical questions regarding the deeper meaning /purpose of life may also spur awakening one's passion: Who we are? Why we are here? How can we make a difference? What excites us? Passion triggers imagination. Albert Einstein said: "Imagination is the highest form of research". Passion makes you feel alive. It speaks through your eyes, feels in your heart, touches your soul, sparks your imagination and nurtures your creativity. Passion is the eternal energy that drives your engine of innovation. But transforming passion into innovation requires developing and nurturing mindset for innovation, overcoming barriers for innovation, understanding the characteristics of innovation, learning thinking tools and skills for innovation and experiencing through the innovation journey. This paper describes the above stages of inspiring innovation.

2. Mindset for Innovation

"*A mindset, in decision theory and general systems theory, refers to a set of assumptions, methods or notations held by one or more people or groups of people which is so established that it creates a powerful incentive within these people or groups to continue to adopt or accept prior behaviors, choices, or tools.*"—Wikipedia. Innovation mindset acts as a triggering mechanism to project the image of perceived future changes through innovation endeavors. Mindset for innovation consists of:

Passion, Proficiency and Persistence: Awakening passion for innovation, acquiring required proficiency and being persistence are the key ingredients for success for innovation.

L-Directed and R-Directed thinking [1] : The left hemisphere of the brain directs the mind for sequential, literal, functional textual and analytical thinking. The right hemisphere of the brain reasoned holistically, recognized patterns, and interpreted emotions and non verbal expressions. It is responsible for art and creativity. Innovation that makes a difference requires the synergy of thinking directed by both left and right sides of the brain.

Seeing connection: We see what are our mind is set to see. Conditioning mind to observe the trend and seeing the connection, and being alert to opportunities are keys to recognizing pattern. Breaking down the existing pattern, and synthesizing new patterns leads to new opportunity and innovation.

Being creative: Creativity is the conceptualization and synthesis of new ideas. Creativity is the heart of innovation. Awakening creativity and conditioning mind to avoid barriers of creativity is absolutely essential.

Challenging conventional thinking: Developing a mindset to challenge conventional thinking and thinking outside the box resulted in numerous breakthroughs and innovations in our society.

Imagination and Visual thinking: Imagination and visual thinking are fundamentals to integrate creativity, design and innovation.

Mindset for innovation should also include developing positive attitude, undertaking risk for rewards, not being afraid of failure, willing to take chances, ability to resource assembling and self-confident, effective/persuasive communication skills, vision and leadership.

3. Overcoming Barriers for Innovation

To overcome barriers for innovation the following habits should be practiced:

1. Avoid looking for "perfect" solution for a particular problem.
2. Always try to find multiple solutions for a single problem.
3. Do not be obsessed to find only logical solutions.
4. Do not constrain yourself to find solutions that are only practical.
5. Try to come up with a simple solution.
6. Try to break the rule.
7. Think outside the box.
8. Think in multi-dimensions.
9. Remember: "Failures are the pillars of success".
10. Do not believe that you are not "creative".

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4. Thinking Tools for Innovation

Creativity is the heart of innovation. The core of creativity is creative thinking and creative imagination. However, what we imagine does not necessarily results into innovation. "Creative thinking in every field begins in nonlogical, nonverbal forms. To think is to feel and to feel is to think. Everyone should receive early and continuing stimulation of visual, aural, and other body senses and learn how to imaginatively recreate sense images. Everyone should explore the feelings and emotions of the body. Everyone should learn to abstract, analogize, and empathize: to transform one to other…." [2]. Creative thinking is integrative and crosses disciplinary boundaries. Innovators must learn how to integrate thinking tools and disciplinary skills. The thirteen thinking tools of the world's most creative people are as follows [2]:

1. Observing: Observing is not just passively looking. It also involves visual perceptions followed by discovery and comprehension of the hidden message/ order in the context of random background.

2. Imaging: Imaging allows inventors to communicate visually. Transform the visual image to imagine the ultimate shape, size, form, movement, smells, tastes and application of the innovation.

3. Abstracting: Abstraction is a simple/basic representation of a detailed/complicated creative concept. It allows innovators to communicate with others to generate curiosity and thought provoking questions.

4. Recognizing Patterns: Pattern recognition involves in the process of analyzing the data, formulating the trend and discovering if there is any pattern exists. It is an extremely important tool for innovation.

5. Forming Pattern: It is the process of forming/synthesizing new pattern either from the elements of old patterns or discovering new pattern from existing data. Learning to create pattern is the key for innovation in every discipline.

6. Analogizing: "Analogy refers to a functional resemblance between things that are otherwise unlike" [2]. All the creative people: artists, architects, musicians, mathematicians, scientists, engineers, inventors and innovators routinely draws analogy from nature and the environments for inspiration of their new creations.

7. Body Thinking: Body thinking involves in thinking with the body and the six senses. Muscular feeling, physical sensations and engagement of mind are essential in body thinking. It helps the innovator to relate how the process/ product/service will influence the user's mind, body and soul.

8. Empathizing: Empathy allows the innovator to comprehend the psychology of the end user. It helps to fine tune the innovation from the user's prospective.

9. Dimensional Thinking: "Dimensional thinking involves moving from 2-D to 3-D or vice versa; mapping or transforming information in one set of dimensions to another set, scaling or alternating the proportions of an object or process within one set of dimensions; and conceptualizing dimensions beyond space and time as we know them" [2].

10. Modeling/Simulation: Modeling and simulation allows the innovator to control the key variables and characterize the cause and effect relationship of critical design parameters.

11. Playing: Play is having fun without responsibility and the consequence of the outcome. Play allows the innovator to break the existing rules, create new rules and inspires to think outside the box. Play nurtures curiosity.

12. Transforming: It is the process of transformation of a concept /idea/product/service from one set of environment/context/characteristics to a completely different one. Transformational thinking gave birth to numerous innovations.

13. Synthesizing: Synthesis involves in creating new things from old ideas, combing existing ideas/products to something new and innovative. Synthesis creates new relationship, new boundaries and new opportunities. It is the ultimate tool for innovation.

To be successful in innovation one must learn and understand how to observe, engage in creative imagination, communicate through abstraction, recognize patterns, forms new patterns, able to analogize, engaged in dimensional and body thinking, empathize, play, model, simulate, transform and synthesize multidisciplinary thoughts and ideas into practical reality.

5. Characteristics of Innovation

The eight important characteristics of innovation can be classified as follows [3]:

1. Design:

Centuries ago, the Greek philosopher Aristotle proposed a doctrine of four causes that explain the essential ingredients that lead to any human creation: Simply stated, everything that we do originates with intentions that take materials and shape them into something that will meet an ultimate goal; thus he spoke of initial, material, formal, and ultimate causes. In other words we have ideas about to how to shape the materials of our world into things that will enhance our process of becoming. While creativity is the ability to see and do something in a new way and may directly impact the initial and material causes, the more formal cause of design helps us to shape and articulate those creative insights. This does not mean to us or to Aristotle that creativity and design are separate and can be treated exclusive of each other; in fact, all of the four causes interweave and become interdependent as the process of anything becoming advances toward fruition. The designer becomes an interface between creativity and function as the designer serves as an explainer or translator, the communication link between the thing and the user, the idea and the reality. The designer gives perceivable shape to whatever is proposed and makes it apprehensible, comprehensible, and potentially attractive. Design must have a purpose and make a difference. It should be aesthetically appealing, emotionally engaging and capture the imagination. Design should cross boundaries and draw a big picture. Differentiating design is one of the most important characteristics for the success of new innovation [4].

2. Functionality:

Functionality is a key characteristic of innovation. It should incorporate improvements of existing features and add new / unique features sought after by the users. The new and innovative functions should spark the user's imagination, awaken their curiosity and please their sensuality.

3 Aesthetics:

In addition to the architectural features (size, shape, dimensions, weight, color, texture, etc.), the new innovation should also be aesthetically harmonious, pleasant, draw emotional attachment and psychological bonding and create good feelings.

4. Environmental Interactions:

The product must be safe to use, easy to maintain, non toxic and non degradable. Use of energy should be minimum and versatile. Improvements of data/ information storage capacity and processing speed of the device are also very important.

5. User Interactions:

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The most important features of this characteristic consist of: user friendliness, simplicity, logical and rational flow of functions and features, short learning curve and minimal mental demand for user interactions. User diversity of age, gender, culture, language, ethnicity and educational background are also very important.

6. Cost and Pricing:

The production cost should be minimized and pricing should be optimized. The pricing should be sensitive to the affordability of the target market and demography.

7. Efficiency:

The product must use the material and energy efficiently. The functionally features must perform with highest efficiency without failures.

8. Sustainability:

This is a very challenging and increasing demanding category of innovation in the market place. Sustainability is the intersection of three main domains: the new innovation must be socially desirable, ecologically viable and economically feasible. The new generations of consumers are very sensitive to sustainable products, processes and services.

Innovators should try to incorporate more than one of the above eight important characteristics in order to be successful in the market place.

6. **The Innovation Journey**

The innovation journey consists of the following iterative decision making processes [5]:

1. Observations of current trends/ patterns and identifying needs, and problems.

2. Formation of Innovation Team (I-Team). “My model for business is The Beatles. They were four guys who kept each other’s kind of negative tendencies in check. They balanced each other and the total was greater than the sum of the parts. That’s how I see business: great things in business are never done by one person, they’re done by a team of people.” – Steve Jobs. Innovation team must include diversity of talents and understanding of vision, missions, and goals for innovation. A schematic diagram of the formation of an I-Team is given in Figure 1.

3. Brainstorming ideas for possible solutions through divergence and convergence thinking.

4. Transformation of an idea to an opportunity and analyze the windows of opportunity. Analysis of opportunity involves in rigorous assessment of the demand, innovation, feasibility and market attraction of the proposed innovative products, processes or services.

5. Evaluation and assessment of opportunity and transforming the creative ideas into practical reality through innovative design.

6. Development of a Proto-type of the design followed by testing, analysis and performance evaluation.

7. Transforming Innovation to Entrepreneurship Venture Development: Entrepreneurship is stimulated by innovation. Transforming innovation in to new products/services and taking it to market involves in performing

feasibility analyses (Product/Service, Industry/Market, Organizational and Financial feasibility), development of business model, business plan, venture plan and securing external investment.

Innovation journey is more important than destination. It takes patience, proficiency, persistence and perseverance to reach at the desired destination.

A schematic diagram of the above stages of the innovation journey is given in Figure 2.

"Creativity is just connecting things. When you ask creative people how they did something, they feel a little guilty because they didn't really do it, they just saw something. It seemed obvious to them after a while. That's because they were able to connect experiences they've had and synthesize new things." – Steve Jobs

The following questions may help to spur the imagination, creativity, design and innovation [6]:

1. Is there a new way to do it?

2. Can you borrow or adopt it?

3. Can you give it a new twist?

4. Do we merely need more of the same?

5. Less of the same?

6. Is there a substitute?

7. Can you rearrange the parts?

8. What if you do the opposite?

9. Can you combine, remix and rematch the ideas and components? Can you put new use of old devices?

10. Can you develop new market/opportunities for old ideas?

Areas of opportunities for innovation journey includes: alternate energy (innovative use of solar energy, low cost water desalination using renewable energy, solar powered medical devices for remote areas, fuel cells using renewable hydrogen etc.), health care (vaccines for infectious diseases, embedded sensors, biometric identification systems etc.), environment (innovative use of non toxic biomaterials, biodegradable materials, toxin materials identification devices), technology (low cost smart phone, low cost broadband delivery system to rural areas), disruptive technologies, education(smart e-textbooks), service, food, consumer products, life style etc.

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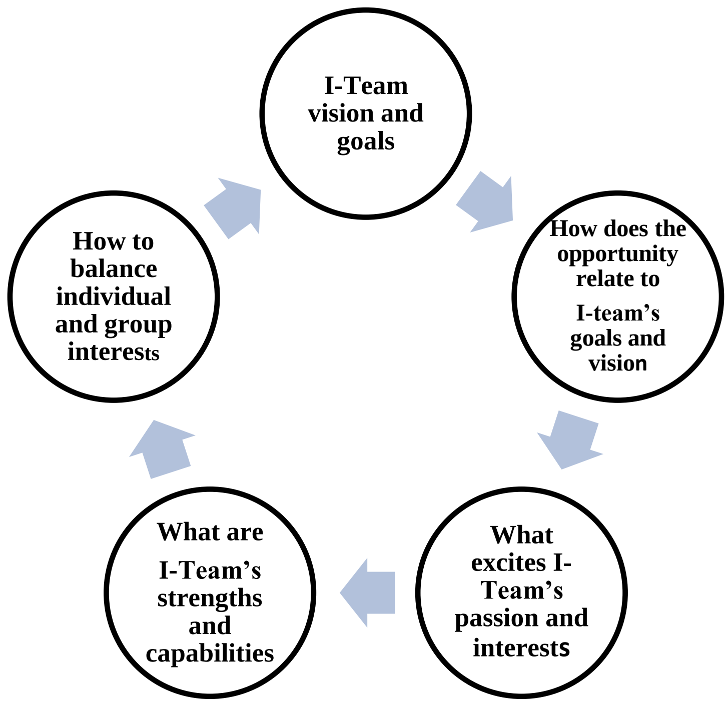

Figure 1. A Schematic Diagram of the Formation of an Innovation Team (I-Team).

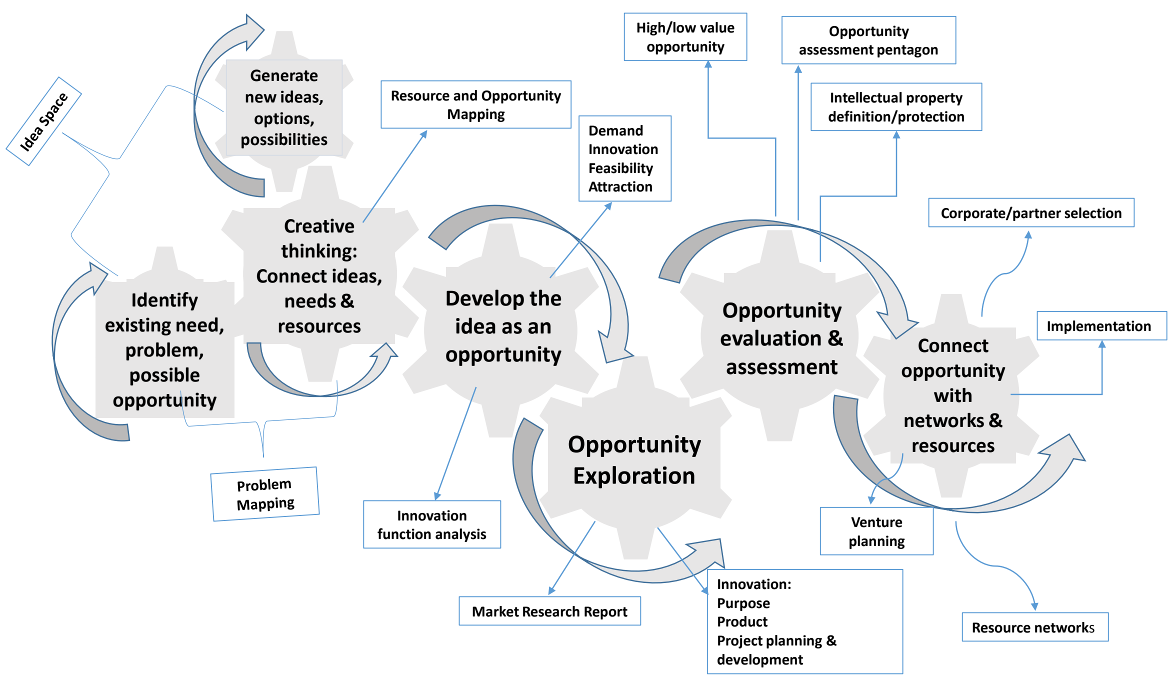

Figure 2. A Schematic diagram of the Innovation Journey [5].

7. Conclusions

Innovation is one of the corner stone of our education for preparing the 21st century workforce to achieve global competitiveness. Innovation engine creates the breakthroughs in clean environment and energy revolution, delivers low cost education and health care, accelerates the development of bio, nano and disruptive technologies, stimulates entrepreneurship, creates new ventures and drives the economic, business, market and capital growth.

Inspiring innovation starts with awakening passion. Turning passion into innovation requires developing and nurturing mindset for innovation, overcoming barriers for innovation, understanding the characteristics of innovation, learning thinking tools and skills for innovation and experiencing through the innovation journey. Innovation journey is a continuous process. It takes patience, proficiency, persistence and perseverance to reach at the desired destination.

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Innovation in Microelectronics Assembly Technology Education

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Abstract

This paper deals with innovative education programme in the microelectronics technology area, containing modern technologies of electronic packaging and interconnection. It is applied at Faculty of Electrical Engineering and Communication in Brno University of Technology. The subject "Modern Microelectronics Technology" gives the fundamental knowledge and skills about "Electronics Hardware" in booth Bachelor´s and Master´s degree program in particular. The content of the lecture is in accordance with the global development and is coordinated with programmes at various universities worldwide. A new idea, and at the same time the main objective in this area is to achieve still closer contact of the University with the industry in terms of technological integration. Lectures and laboratory curricula are described, as well as the supporting project, which is implemented in the form of an integrated circuit, by students in team work organization. Practical training in the microelectronics laboratory forms a very important part of the learning process, which is positive valued by students, and was also awarded by the International Microelectronics Assembly and Packaging Society [1]. The laboratory is based on low cost no-vacuum thick film technology, which allows students to realize various electronics components and also their own integrated circuit. Therefore, the main emphasis is on the acquisition of practical skills and abilities. It also increases students' motivation and their active approach to study. This paper describes the structure of the course and includes also some experience of teaching.

Keywords: *Engineering education, Microelectronics, Electronics hardware, Interdisciplinary subject*

1. Introduction

Microelectronics technology is a very important part of the practical electronics because it creates electronic hardware, which is now included in all industry areas. To have basic ideas about principle of hardware requires some theoretical and practical knowledge for all engineers. The importance of knowledge "hardware" is based on the fact that a large proportion of engineers are in their practice often in contact with electronics. Electronics are everywhere nowadays in various application areas, such as communication and control equipment, consumer sector, medical, automotive, computer science and many others. Well treated with hardware means to save costs, improve quality and also protect the environment and human health.

Microelectronics assembly and packaging technology is one of the emerging areas in today´s electronics. There is an emerging global focus on this domain, inside both academia and industry. It is necessary to explore new learning opportunities that will support not only theoretical but also practical instruction. This requires the introduction of teaching new technical knowledge, both theoretical and experimental. Described is the innovated subject "Modern microelectronic technology", which is part of a programme of study at Brno University of Technology, Faculty of Electrical Engineering and Communication. The Masters study programme is two year programme concentrated on electronics engineering education. The following six branches comprise the programme:

- Microelectronics,
- Electronics, Communication and Informatics,
- Electrical Manufacturing and Management,
- Cybernetics, Control and Measurements,
- Biomedical and Ecological Engineering,
- Power Electrical Engineering.

Modern Microelectronics Technology, in other words "Electronics hardware" is optional subject for branches Microelectronics, Electronics and Communication, Automation and Measurement, Teleinformatics and Power Electrics. Represents advanced technology in terms of components and processes, including partial design rules. Its innovative content is provided below, including a new organization of practical training and links with practice.

2. Fundamental terms and structure of electronics hardware

The Merriam-Webster dictionary offers a definition of the term “technology” as "the practical application of knowledge especially in a particular area" and also "a capability given by the practical application of knowledge". Actually the frequently used term “high technology” can be understood as “scientific technology involving the production or use of advanced or sophisticated devices especially in the fields of electronics and computers”. If we add the term “microelectronics”, then particular area is exactly defined. Then we can express the following definition: “Microelectronics Technology for education process” is science giving knowledge about design, production, use and liquidation of electronics hardware”.

The basis of progress in microelectronics assembly technology and also in electronics hardware is comprised immediately in microelectronics technology development, which is changing the approach of engineers in managing positions to decision-making during recent years. The progress in microelectronics assembly technology is strongly influenced by “technology integration” process that assumes different activity sectors together, as is illustrated in Fig. 1.

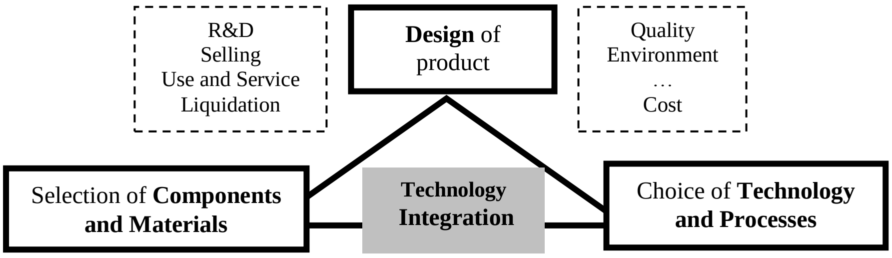

Figure 1. Explanation of the term “Technology integration”

Technological integration requires the basic knowledge of many formerly independent areas, as system engineering, material science, computer practicality, thermal management, quality and also environmental management etc Also selected rules of general management are necessary for good understanding and decision-making ability in this area. The development of new products is more complex and sophisticated and asks approach that is ever more open than in the past time. Also knowledge of electronics hardware becomes highly interdisciplinary area containing different sectors as could be seen in Fig. 2.

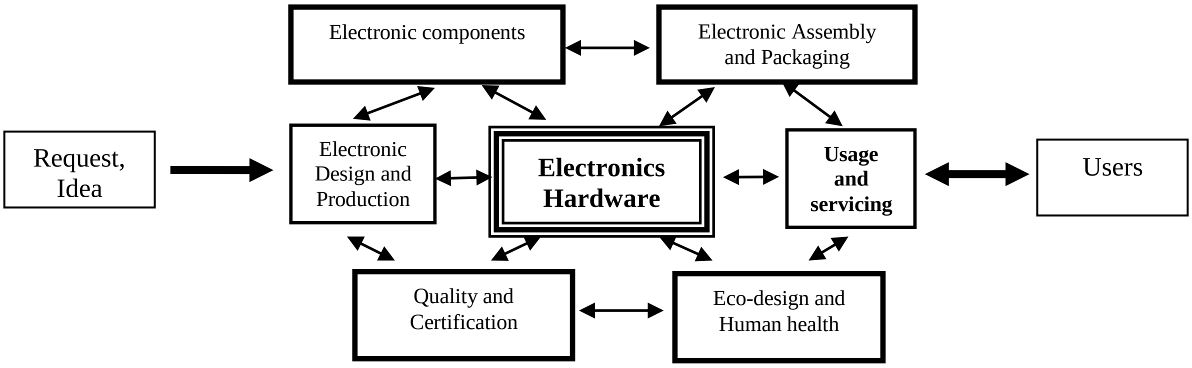

Figure 2. Main segments of electronics hardware in the context of technological integration

Electronics hardware consists of multiple areas of expertise that are logically connected. In the microelectronics assembly technology sector increasingly important core area of knowledge, which deals with electronics hardware is “Electronics Packaging and Interconnection” [2]. This area becomes to be more and more complex and includes more subjects.

The fundamental part of today’s Microsystems is the semiconductor chip, which in comparison with human body seems to be something like the brain of the system (Fig. 3). To realise some functions or activity other apparatuses are also necessary, such as heart, hands, legs and all the body with sensing and executive parts. In electronics system the package is like the body, sensors as receptors, blood as electrical current, heart as source etc.. Development of semiconductor chips has made enormous strong progress in the end of last century and this continues without end. The same situation didn’t set by packaging, interconnection and assembly technology processes in. That means there is strong need to push assembly technology more intensive to achieve necessary technical level.

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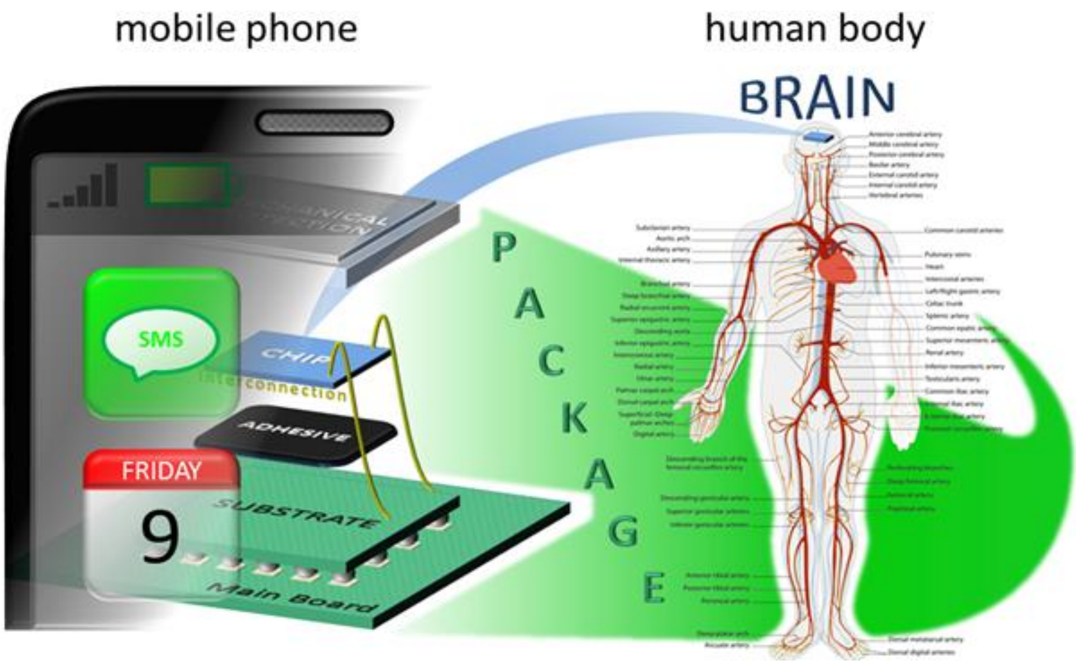

Figure 3. Comparing an electronics system with the human body

Pyramid schema giving more concrete overview of knowledge in the area of electronics hardware is shown in Fig. 4. The “core” thematic topics for electronics packaging are labeled using strong frame. An optimum and effective range of individual topics is achieved by including practical laboratory training, and external cooperation with research and production entities.

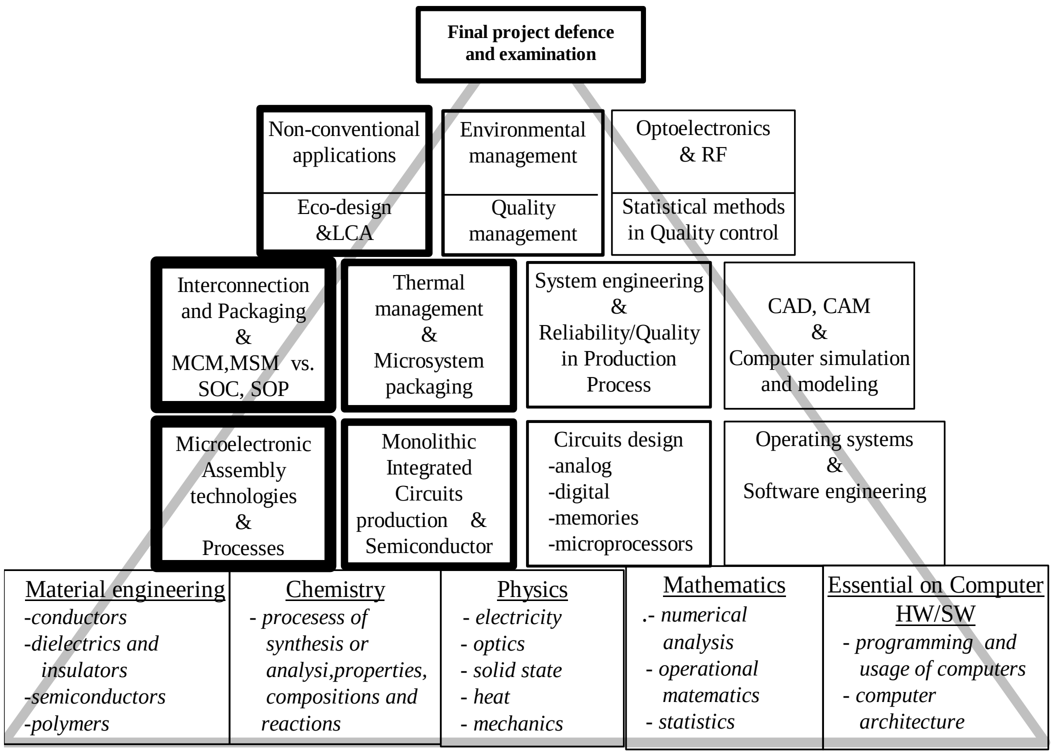

Figure 4. Basic structure of the microelectronics education system

The base is founded by physics, chemistry and mathematics, which are the foundations of science already in secondary schools. Core thematic topics are:

- Microelectronic Assembly Technologies and Processes
- Interconnection and Packaging including Electronics Packages
- Microsystems Packaging and Non-conventional applications

3. Curriculum for electronics hardware education

The main objective of this course is to teach students to orient and manage in electronics hardware. That is why the theory is strongly linked to experimental teaching. That is the only way to teach students the basic skills such as soldering, fault diagnosis and general troubleshooting. The course focuses on current and future electronics assembly and packaging technology process, which means all the sequential process steps from the semiconductor chips, through assembly processes, handling, use and repair of hardware (PC, mobile phones, displays, various control devices and measuring equipment products etc.). This knowledge of passive and active components, switches, connectors, batteries, displays, etc., can play a key role in the final decision, and thus contribute to technical and economic success. On that basis, a Curriculum for modern microelectronics technology training focused on hardware (Fig.5) has been prepared which has the following contents:

- Introduction to Electronics technology, Hardware and Substrates for Microelectronics Assembly

- Semiconductor Chips and its Performance in context of interconnection and packaging

- Passive Elements including Embedded, its Performance and Selection

- Thick & Thin Film Technologies and Hybrid Integrated Circuit´s (HIC)

- Assembly Technologies for Electronic Circuits –Surface Mount Technology (SMT), Low Temperature Cofired Ceramics (LTCC)

- Electronic Packaging - Fundamentals of Electrical Design and Thermal Management

- Soldering as decisive Operation for Electronic Systems Reliability

- Quality Engineering and Total Quality Management (TQM), Statistic Process Control (SPC), Directives –WEEE, RoHS, EuP, CE

- Life Cycle Assessment, Eco-design and Electronics Impact on Environment

- Unconventional applications implemented by non-vacuum processes

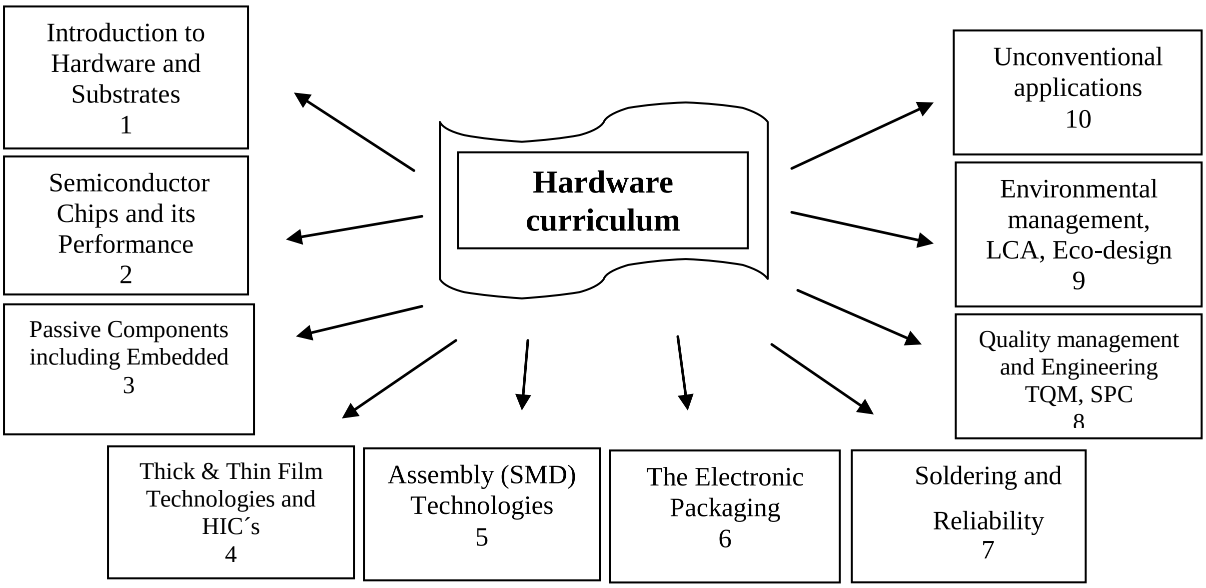

Figure 5. Syllabus of Microelectronics Technology regarding “Electronics hardware”

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This programme is arranged in two levels, for Bachelor study (Microelectronics Technology and Components), and for Master study (Modern Microelectronics Technologies). Both courses are organized in one semester period with weakly programmes consisting of one theoretical lesson (3 hours) and lab lesson every two weeks (4 hours).

The course includes twelve classroom lectures as shown in Fig. 5, where are explained the basic principles and core fundamentals to each topic. Contemporary runs laboratory exercises, which are organized in five lessons, each lasts four hours. This experimental learning is arranged in the time- and cost-constrained environment of university, where Microelectronics assembly technology lab based on non-vacuum processes is utilized. Students complete during this course in one semester the main process steps of hybrid integrated circuit realization, starting with design and finishing with packaging and testing. They learn the theoretical knowledge through own skills in practical experience. The five experimental lab exercises are following:

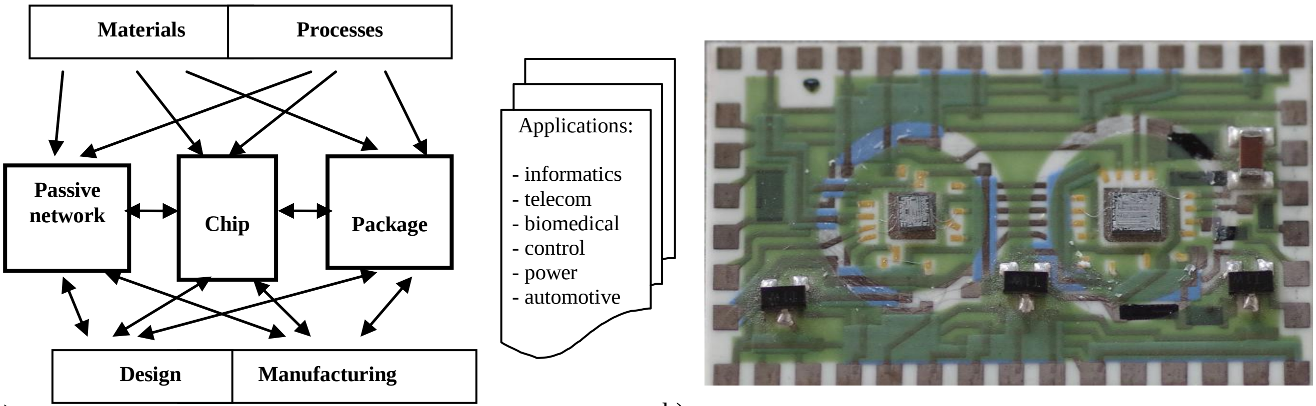
(1) Passive network, design of networks for main boards, screen printing, sintering, Thick Film Hybrid integrated circuits (Each student makes the design of topology of thick film hybrid integrated circuits, prepares the masks for screens and print patterns on the ceramic substrate, which are sintered in the passive network – practical skills are design, printing, sintering)

(2) Passive network trimming and evaluation, sheet resistance calculation and use of statistical tools, temperature coefficient measurement (Thick film resistors are measured and statistical evaluated, after it are trimmed in YAG laser and Temperature Coefficient of Resistivity is measured and calculated) – practical skills are touch setting resistors and their values

(3) Mounting of semiconductor chips – wire bonding, soldering and adhesive use, surface mount technology application (The main technological operation for semiconductor bare chip connection known wire bonding is demonstrated and approved, thermosonic and thermo-compression equipment is utilized, SMD are mounted by reflow soldering or by conductive adhesives) – practical skills are treatment components and their connections including soldering

(4) Thermal management analysis, ANSYS application, packaging and testing (In the first part is presented application of ANSYS software for mechanical, thermal and electrical analyzes of two basic parts of electronic components – solder joints and electronics packages, in the second part is integrated circuit encapsulated by fluidization process and insulating resistivity between leads is measured) – practical skills are adoption soldering and packaging, simulation in ANSYS for microelectronics hardware with a basic knowledge of physics (Newton and Hooke's Law)

(5) Circuit testing, quality implementation (setting and measuring control parameters) in electronics production process and tools, Eco-design application in electronics and human health, legislation (This exercise is oriented to testing, statistical evaluation, Eco-design and its methods and tools (MET matrix, TPI indicator), next is demonstrated goal and application of Life Cycle Assessment including case studies, where comparison is made of the ecological impact of various products) – practical skills are measurement inside integrated circuits, understanding the importance of quality and environment management



a) b)

Figure 6. Schematic design of lab exercises process (a) and realized IC (b)

In the final lab exercise students take one functional HIC oneself. Some of experiments or demonstrations may be conducted in virtual form, which is organized on the base of e-learning [3]. Students have in experimental part good opportunity to improve their practical skills during complete process of integration of simple electronic circuits which makes the base of electronics system. All technological operations in the lab are based on non-vacuum processes, where the main technology is thick film realized on ceramic substrate. During experimental work students teach, probe and verify fundamentals of microelectronics and improve basic theoretical knowledge. They also learn to understand relationships and links between design and production phase, and also the main aspects that influence quality and cost. All subject matter is completed with environmental aspects.

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Most of the theoretical hardware issues can only be appreciated if students have a chance to work in the laboratory. To create a demanding laboratory for just one course would be uneconomic. Fortunately the lab of Microelectronics Assembly Technology at FEEC in BUT is built systematically, and the scientific research work is utilized also for diploma theses, and is planned also for CEITEC, where strong reverse collaboration is proposed [4], [5].

4. Conclusion

Two main objectives are presented in this paper. The first is the presentation of a new curriculum for electronics hardware education with supporting lab exercises, which offers for students the possibility to receive practical skills in the field of modern electronics technology, including the design and building of their own hybrid integrated circuits. The basic process for experiments is thick film technology that allows realization of various electronics components including hybrid integrated circuits [6]. The lab is non-vacuum and arrangement of the basic line is not expensive - the estimated cost should be around 50 kEUR. The second scope is the necessity to collaborate with research institutions and industry. The fact that the laboratory specializes in non-vacuum packaging and interconnect technology (including mounting of bare chips of IC 's), is requested by industry, particularly from small and medium-sized enterprises. This step is supported through strong collaboration with CEITEC and IMAPS (International Microelectronics, Assembly and Packaging Society). The layout and organization of laboratory also offers some special services in this area, not only for students of all disciplines, but also for companies [7]. The lab is systematically built as multi-purpose lab where main goals to achieve are:

- educate and provide hands-on research experience for electronics engineers and managers in electrical area to take responsibility for future of microelectronics industry,
- provide quality and timely research on microelectronics topics, such as electronics assembly, interconnection and packaging,
- provide assistance to all students and the industry for their immediate needs.

The general output is to learn the ability to navigate, especially in both technical and managerial skills in electronics hardware solutions. A manager who knows how it works, what are the basic principles of electronics hardware, has knowledge about the reliability, quality and impact on the environment (eco-design) may choose a better solution than one without such understanding. A better solution will also result in a better economic outcome. This knowledge helps to manage decisions about electrical / electronic equipment throughout its life cycle, which gives positive results in reducing costs, including energy savings, reduced environmental impact, and many others.

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Innovation Lessons to Apply To Engineering Education

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Abstract

Increasingly, engineering graduates are expected to contribute to innovation within the companies or agencies for which they work. Engineering education needs to begin preparing graduates to contribute and succeed in that environment. Many of the most pertinent findings considered for curriculum inclusion originated in other disciplines. Several possible approaches are presented in this paper with discussion of appropriateness and ease of adoption in the curriculum. These concepts will be applied to a senior design capstone course, while also describing how they apply to PEER Consultants, P.C. Among considerations are teams, organizational structures, space, and finding others. A number of techniques for enhancing team performance and innovation are presented, including ideation, design thinking, liberating structures, and brainstorming. Team member accountability is a key element, and team formation should not be random. Use of other organizations, both within and outside the university, is discussed as possible support. The value of interdisciplinary collaboration is noted.

Keywords: *Innovation, Teams, Organization*

1. Introduction / Problem for Study

Increasingly, engineering graduates are expected to contribute to innovation. Engineering education needs to begin preparing graduates to succeed in that environment. Many of the most pertinent findings considered for curriculum inclusion originated in other disciplines. Several possible approaches are presented in this paper with discussion of appropriateness for adoption in the curriculum. In addition, these concepts will be considered for use in a consulting firm. The senior author completed a non-traditional sabbatical spent with a highly successful, thirty-seven year old, medium-size environmental consulting firm. PEER Consultants, P.C., is headquartered in Washington, DC with offices in Baltimore, MD; Burlington, MA; Clearwater, FL; and Laurel, MD. PEER, with over 100 employees, primarily works with municipalities and has performed work in a number of environmental areas. All of the ideas for PEER can be viewed as either possibilities for a course or, at the least, exposing students to concepts they may experience in practice.

The next several sections outline findings on barriers to innovation and techniques to enhance innovation identified through review of literature. These are presented to help readers identify strategies for either engineering education or adoption in a company.

The objective is to move beyond the concept of an individual, "heroic" creator to a culture of consistent innovation. One such approach has been developed over the last twenty-five years and is called design thinking [1]. It is based on understanding that movement from creativity to innovation entails several steps, including Inspiration - which also helps bridge the gap from creativity; Ideation; and Implementation. Ultimately, this procedure must lead to improved designs, products, or processes that enhance a firm's market position and profitability

2. Effect of Culture

A study by the American Society of Civil Engineers (ACSE) [2] considered the personality types of professional employees of consulting engineering firms. Their study indicated that a greater percentage of consulting engineers have a type preference for introversion over extroversion, intuition over sensing, thinking over feeling, and judging over perceiving than the national US population. Substantially more consulting engineers have an intuition-thinking temperament than the national US population. The author has conducted numerous studies of the Myers-Briggs type indicator in the student population and faculties within universities. It is not uncommon to find, for example, that seventy-five percent or more of engineering faculty members are

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introverts. This study by ASCE suggests a predominant type of INTJ. Unfortunately, universities and in particular colleges of engineering have not been very effective in embracing those with an extroversion and feeling preference. Some studies have indicated that, in fact, most of those in that category have been driven from the engineering curriculum. In this particular setting, this means that communication, without intentional efforts, may be difficult between consulting engineers, clients, the public, and non-engineers within the consulting engineering firm. This must be considered as new approaches are crafted.

3. Effect of Organizational Structure

These elements of organizations are critical to possibilities for innovation. As a result, students need at least some understanding of any potential barriers that may exist and how to navigate within different systems. It is not impossible to be innovative in the latter case, but it entails more effort and identification of channels to success. Some engineers become frustrated when in such an organization, and this needs to be managed for success.

The noted management guru Peter Drucker [3] observed that the role of a leader is to mobilize the community and to step in when there is an emergency. Mobilization of the community is an important objective, but it may not be easily attainable. It certainly does not happen at random. This implies there must be a strong sense of engagement within the community, and efforts must be undertaken to ensure that is true. This dovetails with several of the other efforts detailed here.

In Rosabeth Moss Kanter's seminal study [4] of the behavior within organizations, she found that innovative organizations were horizontally integrated, while those that were not innovative were segmentally organized. The terminology segmentally organized means a traditional hierarchical structure, with silos formed according to reporting structures. There are a number ways around this, but it seems important to identify directions and allow the organizational structure to surface fully from the organization's objectives. Wheatley [5] proposed free-flowing information, individual empowerment, relationship networks, and organizational change that evolves organically. However, it is quite likely that while there are many organizational structures possible, a matrix structure will fit many organizations. The opportunity exists to create innovation while at the same time having the ability to understand what is going on in the organization and to have accountability.

Understanding communications channels within an organization is a critical element of opening up more channels. The concept of diffusion of innovation [6] helps understand these roles and the concept of change agents and trusted agents. It also helps understand how to enable those in the organization to craft their own approaches and to be understood. The critical process of diffusion of innovation can help reach influencers within the organization.

4. Teams and Tools for Successful Innovation

It is widely recognized that bringing together people with different backgrounds can change the "design space" and potentially lead to innovative solutions. This is most likely to occur if team members have learned how to collaborate effectively. Given the expectation that most graduates will work in teams, this further increases the need for engineering curricula to build team skills. Research of team makeup on likely success and innovation of their efforts can lead to better team selection and learning processes. Barriers to implementing these improved understandings in curricula and in companies must be understood to craft effective solutions.

PEER is undertaking development of a strategic plan. True to its core values, it is working to engage everyone in the firm, and this process requires enhanced and ongoing communications. Give the number of offices, plus the existence of embedded employees, this is not a trivial matter. Several approaches are being considered, including both face-to-face meetings and further use of technology. Since PEER is also moving toward more team efforts, it will also be necessary to better prepare people to successfully operate in teams.

Teams have been studied in many situations, and much is known about what teams need to do to be successful, as well as assuring contributions from everyone. [7] - [10] Diversity in many forms is extremely helpful if you want teams to develop innovative solutions [11]. Diversity can have many characteristics. Certainly, one looks for people with different experiences, different personality types, different cultural backgrounds, different genders, different disciplines, and different levels of experience. Therefore care should be taken in the way in which teams are selected. This methodology tries to assure the diversity of thoughts and experiences that one would like to see. Further, since team designs often require peer evaluations, good friends may be more reluctant to be as forthright in ratings and comments. PEER's make-up provides real opportunities to benefit from diversity within its employees and teams.

CATME (Comprehensive Assessment of Team member Effectiveness) [12] was formulated from a research project as a means simply of assessing individual contributions to team success (or peer evaluation). Since that time, it has added a number of tools to its capabilities, including training team members, faculty management guidelines, and team schedule arrangements. While this was prepared based on experience in higher education, it has many tools and approaches that may be useful for companies such as PEER, including team formation and pragmatic issues such as scheduling and finding an available room (although the last task can be done electronically through many platforms.)

Brainstorming is a tool in use for several decades, and it has many variants. Recent research [13] suggests some factors need to be considered for the best results. Previously, the feeling was that all ideas were accepted with no discussion, and possibly with a smile. However, studies have shown that some challenges and disagreement (still done with respect) can not only significantly increase the number of ideas generated, but also the quality of ideas.

Ideation [14] is the formation of concepts and ideas. In the innovation process, this is a significant part of a successful effort. There are numerous tools for teams to use for ideation, including some of the tools mentioned herein.

Design thinking [1] has been very influential for over twenty years. It has been called "a human-centered, prototype-driven process for innovation that can be applied to product, service, and business design." [1] The process begins with efforts to develop empathy for the customer, to increase the likelihood of acceptance. This leads to steps of defining the problems, proposing solutions (ideation), and then development of the selected solution. This is not just to design products, but it has been used increasingly to improve organizations. The underlying principles are important to the institution of an engaged workforce within the organization. It can also be implemented in a senior design course.

The use of liberating structures [15] for engaging people has existed for about 15 years, and it has begun to really take hold. This has found usefulness within academic settings and a wide variety of industries. This technique consists of use of a series of simple (almost simplistic) constructs to break down hidden structures in a team or organization. There are examples of successful use of liberating structures, in diverse fields, such as higher education, healthcare industry, restructuring and reorganizing companies, and even passing legislation. It recognizes that each of us are different and that we need a means by which everyone contributes to the dialogue and a creative solution. The success of this technique in a variety of settings suggests it can be very fruitful to improve dialogs within companies, as well as within design teams and senior capstone course. These liberating structures will be used in PEER to increase engagement throughout the company.

In recent years there has been an extreme growth of the concept of Idea Fests (or Idea Festival or Ideas Festival) to advance innovative thinking and collaboration [16]. At the highest level, this can represent efforts by companies and large organizations to find approaches, processes, and new markets that may be useful in the future. Today, an increasing number of universities are holding their own Idea Fests. Companies may do this virtually through electronic submission of ideas. There may be a multiple step process, beginning with a brief idea statement, followed by a white paper from selected ideas, and finally a longer proposal from the few selected for continuing. In some cases, companies also follow up with a celebration and perhaps a speaker to emphasize the importance of innovation. A smaller scale approach is being considered at UTEP to build excitement for the design process.

5. Space: Barriers and Means of Innovation Enhancement

The physical layout of space within a company can encourage or hamper innovation. Graduates will be well-served to understand elements of space and its impact on free-flowing exchanges. Techniques to create the engineer's own communications networks will be described, both using and circumventing space design.

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Physical separation is a barrier to having free-flowing communications. Many studies have indicated that distance between people, even between floors of a building or great distances on the same floor, significantly decreases communications. Many of the elements of space design have attempted to overcome this in a variety of fashions. Where people are located in different locations, one has to try to find a combination of technologies and occasional face-to-face meetings to assure that people are communicating and contributing to innovation.

There has been a strong move away from cubicles to enhance interaction [16], which it certainly does. However, studies [17], [18] also express concern for the noise created in such an environment and its resultant negative impact on productivity. A lack of privacy is also a concern. For example, it may be difficult, if not impossible, to have a confidential phone call with a client in such a setting. There are growing efforts, e.g., to create more openness while maintains both privacy and quiet. However, the design of space and traffic flow to create intentional serendipity [19] remains an essential part of providing an enhanced set of interactions. The story of Building 20 at MIT is full of ideas that have emerged from people who were housed together, more by need for space than by any planned collaboration. [13]

The senior author had a graduate team study in detail these interactions in a variety of industries for a doctoral class project [20]. The results are very revealing in the ways that companies try to create a feeling of ownership while growing collaboration. Apple, among others, has created a structure within its buildings [20] that requires everyone to traverse through a common area, no matter where they are going. This enhances the likelihood of a chance meeting. Various other companies, such as Amazon and Google, for example, have many collaboration spaces available. Another approach which has grown is the practice of hoteling [21], or the practice of providing office space to employees on an as-needed basis instead of by means of a permanent workspace. PEER already partially practices this, but will be looking at other space designs. It is noted [21] that when space is redesigned, the purpose must be stated before beginning. Many companies, especially with people who are often out of the office, use hoteling or other related techniques as a means to save money on space, but this must also be balanced against other objectives. The senior author, during his sabbatical, discovered that the United States Department of Agriculture uses a variant of this approach. There are firms that do space design to accomplish these objectives, and they have a long history of successful efforts. PEER is exploring the possibility of finding a local university with a graduate, project-based course to use their situation for a class project. This can look not only at physical space, but also at how PEER can enhance communications and collaboration between its various offices.

It may sometimes be beneficial to have some dedicated space, especially for extended projects. Harvey Mudd's longstanding Engineering Design Clinic [22] does have space for students to leave their project work, as does UTEP and others. In a company, this might also be beneficial for teams in companies with a special focus, such as preparation of a proposal.

6. Finding Other Minds

Beyond the tools indicated to enhance innovation within the teams and organization, engineers need to be willing to reach outside their own network to challenge their thinking and help fuel innovation. This can begin during the engineering curriculum by requiring that they connect with some colleagues at other locations (companies, industry, universities). Given their facility with various social media and other electronic communication, this is generally not too difficult to accomplish.

The "hero" approach to innovation implies that people are born creative and that only a few can contribute to innovative solutions. Pablo Picasso has been cited as one of the most innovative artists of recent history. Obviously, he is bright, motivated, and receptive to new ideas. However, one cannot overlook the time he spent in Paris, the artists with whom he worked, and the general environment at that time. These clearly impacted his directions. If one looks at some of his earlier work, it is excellent and compelling, but it is very different from what was seen later in his career.

When seeking "other minds," one can do this on their own and/or as a team effort. One approach is intended to actually free your mind and enable being more receptive to new thoughts, less burdened by the day-to-day items. This is called "morning pages," [23] and it began in the creative world of art. This approach suggests writing seven-hundred and fifty words each morning, writing whatever is on one's mind. This is more of an individual endeavor, but it may bear fruit in terms of innovation. It has been cited as successful in many fields.

There are many ways to find others who work in areas related to the role an individual, team, or organization plays. These can often be identified through an on-line search. Once identified, one can reach out to those individuals or organizations to possibly share with each other. Of course, a response may not be received, but it cannot hurt to try. In some cases, work done by the other party can be reviewed on-line or in print. Networking can often be achieved at professional meetings as well.

In addition to the development of networks with those in similar work areas, innovation can be enhanced by developing relationships with people outside one's work area. It can be very fruitful to read outside one's area and to seek out others, possibly even from totally unrelated fields. The gains in insight will more than make up for any discomfort faced.

7. Conclusions

This paper has attempted to provide a list of possible considerations and approaches to create an engaged and innovative organization, whether that is a team or a large organization. Each entity must establish its own objectives and understand its own culture. Many of the tools can be used together to facilitate engagement. However, one must avoid the temptation to change everything overnight. Change is stressful, and it must be managed carefully.

Some of the ideas presented here can be directly used within an engineering curriculum. Others can be presented within the curriculum or informally as a means of exposing students to approaches they may see in industry. Not only will that help them choose a work opportunity in which they feel comfortable, but they may be able to avoid pitfalls and possibly even contribute to their employer becoming more innovative and inclusive.

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Continuous Quality Improvement of Leadership Education Program through PDCA Cycle

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Abstract

The reinforcement of quality assurance system in university education is in great demand. With the goal of quality assurance of a class curriculum, we applied the Plan-Do-Check-Act (PDCA) cycle on leadership education on graduate students of engineering, resulting in seven years of continuously improved quality of the education program in which students achieved their learning goals. The traditional leadership education only gave students knowledge regarding leadership in the form of lectures. Therefore, how to apply this knowledge through students' action has been a big issue for them. To improve leadership ability of students, we introduced leadership education program which integrating knowledge, simulated experiences, and real actions. This leadership education program was conducted in the Masters program at the Shibaura Institute of Technology's Graduate School of Engineering and Science between 2008 and 2013. We measured the extent to which students achieved their goals, combining diagnostic, formative, and overall evaluations. With evaluation results of clarified learning outcomes, a PDCA cycle was repeated in order to improve quality of the education program in three stages. We validated that this cycle led to the achievement to produce effective leadership actions of students.

Keywords: *leadership, quality improvement, PDCA, evaluation.*

1. Introduction

The importance of university education is being stressed, and reinforcement of quality assurance system in education is in great demand. Higher education institutes of engineering are expected to facilitate information processing, knowledge of communication techniques, and project management as part of their fundamental education programs, as well as give students chances to execute teamwork and leadership as applied skills.

The traditional leadership education only gave students knowledge regarding leadership in the form of lectures. Therefore, how to apply this knowledge through students' action has been a big issue for them. To improve leadership ability of students, we introduced leadership education program which integrating knowledge, simulated experiences, and real actions. Thus, we created a new leadership education program in order to enhance students' actions, which in turn led an improvement of the quality of the educational method.

This leadership education program was conducted in the Masters program at the Shibaura Institute of Technology's Graduate School of Engineering and Science between 2008 and 2013. We measured the extent to which students achieved their goals in the program. With evaluation results of clarified learning outcomes, a PDCA cycle is repeated in order to improve quality of the education program in three stages.

Few studies have reported on a concrete method for improving of class curriculum through PDCA cycle. Mine proposed a new methodology for improvement of the social studies lesson, namely, spiral PDCA cycle. This spiral PDCA cycle consists of decision of lesson type by learning outcome at the first stage, PDCA cycle for the lesson according to each quality formation at the second stage, and PDCA cycle with which the lesson is improved by examining and then looking down upon the difference between the relativized view on the lesson, upon which the practitioner depends, and other views on the lesson at the third stage [1]. Otsuka et al. has reported a system model to support the PDCA cycle as a whole, and implement a system based on the model for a teaching and assessment support system [2]. Ishii has reported learning records to make students discover subjects through a cooperative self-instruction based on the PDCA cycle in the PBL education [3].

The purpose of this paper is to report the continuous quality improvement of leadership education program through PDCA cycle.

2. The PDCA Cycle to Assure Quality in Leadership Education

We created the PDCA cycle to assure and improve quality in education in order for students to achieve their set learning goals. Our intention for this PDCA cycle is that students, by gaining leadership skills, can become engineers and execute their tasks at appropriate levels in the society.

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2.1. P (Plan): Contents and Levels of Learning and Educational Achievement Goals

We set contents and levels of learning and educational achievement goals.
① Contents of Learning and Educational Achievement Goals

- To understand systematic knowledge of human skills required in conducting project activities.
- To execute human skills and leadership in technical activities in science and engineering.
- To set action goals by reviewing their own human skills objectively.

② Levels of Learning and Educational Achievement Goals
This leadership education has Level 1 “knowledge,” Level 2 “consciousness”, Level 3 “action”, and level 4 “mastery” (Table 1). In contrast, the traditional leadership education only provided level 1 “gaining knowledge”, and had no curriculum designed to transform knowledge into action.

Table 1. Leadership Educational Achievement Level

	Learning Level		Goal Content
	Level 1	Know	Understand necessary knowledge to act leadership
	Level 2	Conceive	Realize needs of behavioral change and improvement point of daily action to reflect on oneself through the simulated experience
	Level 3	Act	Act as what he/she did in simulated experience, in the real situation
	Level 4	Master	Establish new routine by repeating the act

2.2. D (Do): Educational Method, Program Design for Goal Achievement

This leadership education is intended for students not only to gain traditional knowledge, but also to facilitate them applying the gained knowledge. The intent is also to enhance the transformation of their actions into solidly embedded leadership qualities. Therefore, the traditional lecture-centered education method was required to shift quality-wise. To realize this quality shift, the following education method and program design were cornerstones.

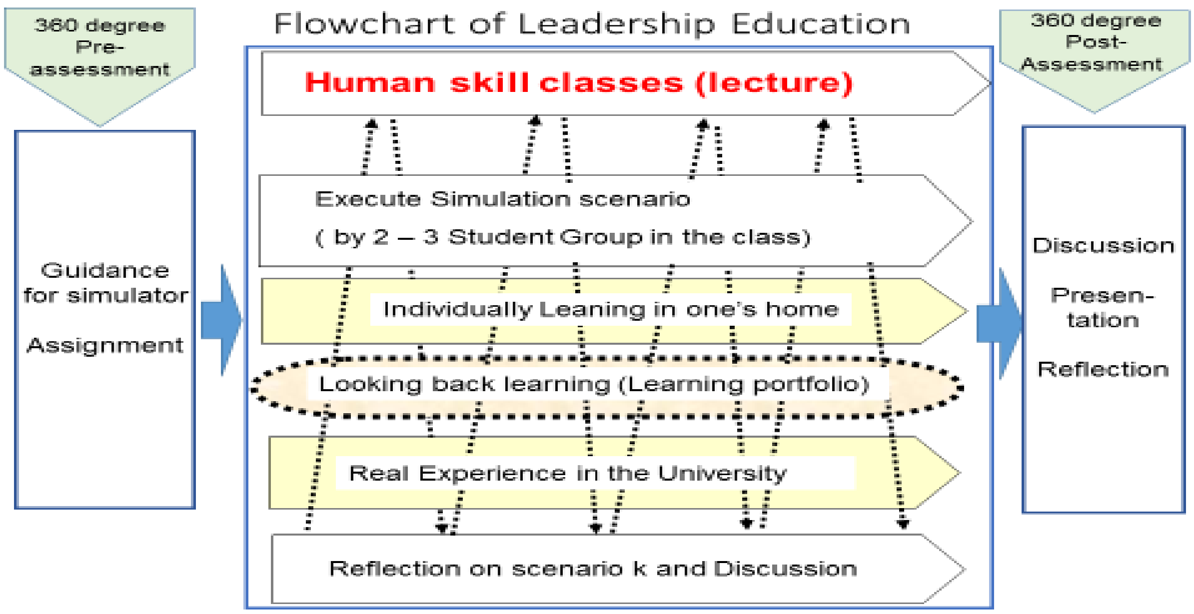

Figure 1. Leadership Education Program Design

① Utilization of Simulation for Transformation of Action

In order to enhance transformation of action, we utilize simulation, which is a training tool providing repetitive practices and simulated experiences. A student can be less resistant to being a leader following repeated practices of leadership actions in a simulation. Hence, the simulation is the bridge between knowledge and realization. Also, with continuous repeated practices a student gets accustomed to act in a new way.

② Leadership Education Program Design

We made a program for students to have consciousness, actions, and mastery through a continuous cycle combined with knowledge, simulated experiences, and application in reality. Also, using diagnostic, formative, and overall evaluations, we measured the degree of achievements of students' study goals, and visualized students' achievements. Moreover, this design promotes active leadership actions outside of a seminar room: whether in home or school (Figure 1).

2.3. C (Check): Evaluation Method to Assess Goal Achievement

We check whether students achieved their learning goals, systematically combining 360-degree assessments, Rubrics, learning portfolios, student achievement interviews, and their emotional intelligence quotients.

2.4. A (Act): Improvement of Overall Education Program Based on Assessment Results

Using evaluation results we monitor where students did not reach their initial target values. For improvement of the overall education program we examine teachers' teaching methods, curriculum designs, study evaluation methods, study support systems and methods, as well as students' study time outside of their class rooms.

3. Quality Improvement of Leadership Education Program

This leadership education program has been conducted since 2008. The above PDCA cycle has been repeated in order to improve quality of the education program in three stages (Program A→B→ C)（Figure 2） [4] - [6].

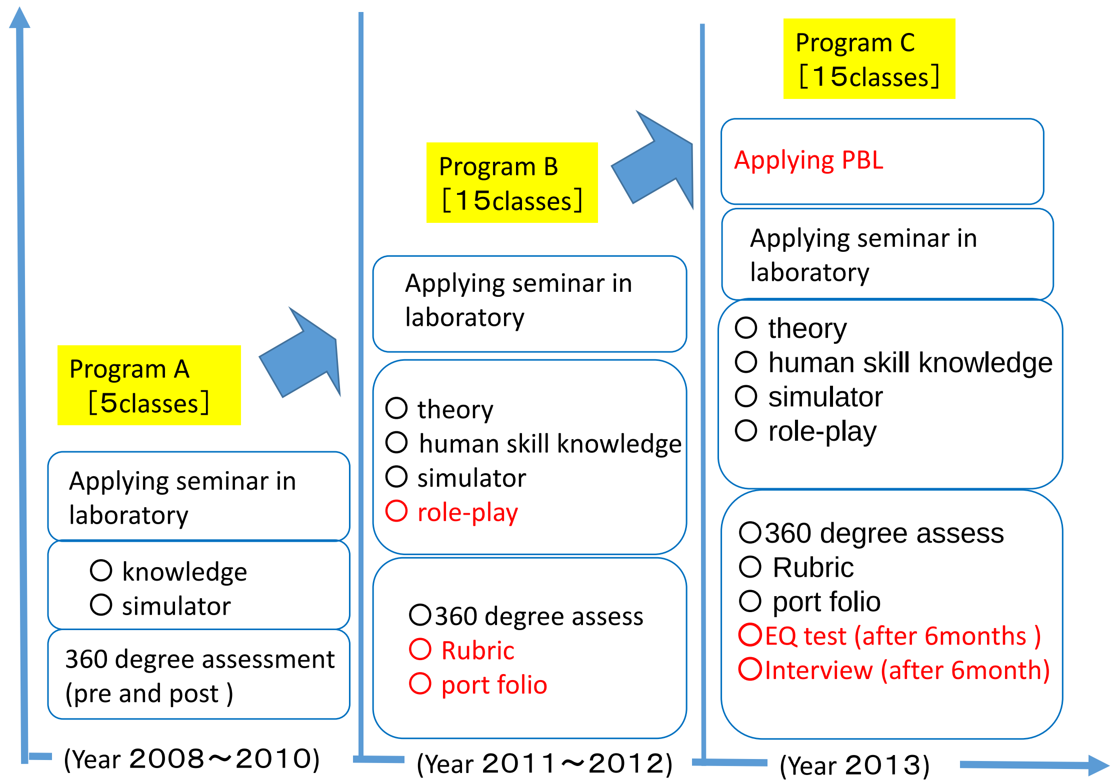

Figure 2. Leadership Education Program Improvement

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4. Continuous and Gradual Quality Improvement and Goal Attainment Level

4.1. Stage 1 （Program A）

Program A was conducted between the 2008 and 2010 fiscal years. Students first acquired knowledge and theory on leadership. Then for their application students utilized simulation to experience leadership actions many times. Simulation provided a safe environment in which they could try out many different approaches, and students could widen their leadership actions in various situations. Also, they realized the tendencies of their own thoughts and actions via simulation, and got clues to improve their actions. In the next step, students applied the above simulated experiences in actually taking leadership in their research seminar and lives. Moreover, they reflected on their real actions and again trained themselves with simulation. This cycle was continuously repeated. A 360-degree assessment was carried out by teachers, senior, and junior students before and after the class. With assessment results, we made sure that students were able to apply simulated experiences for their actions in research laboratories. The Level 3 "action" was achieved (Figure 3). In particular, the achievement skills for their goals, as well as the control skills of tense emotion, were raised.

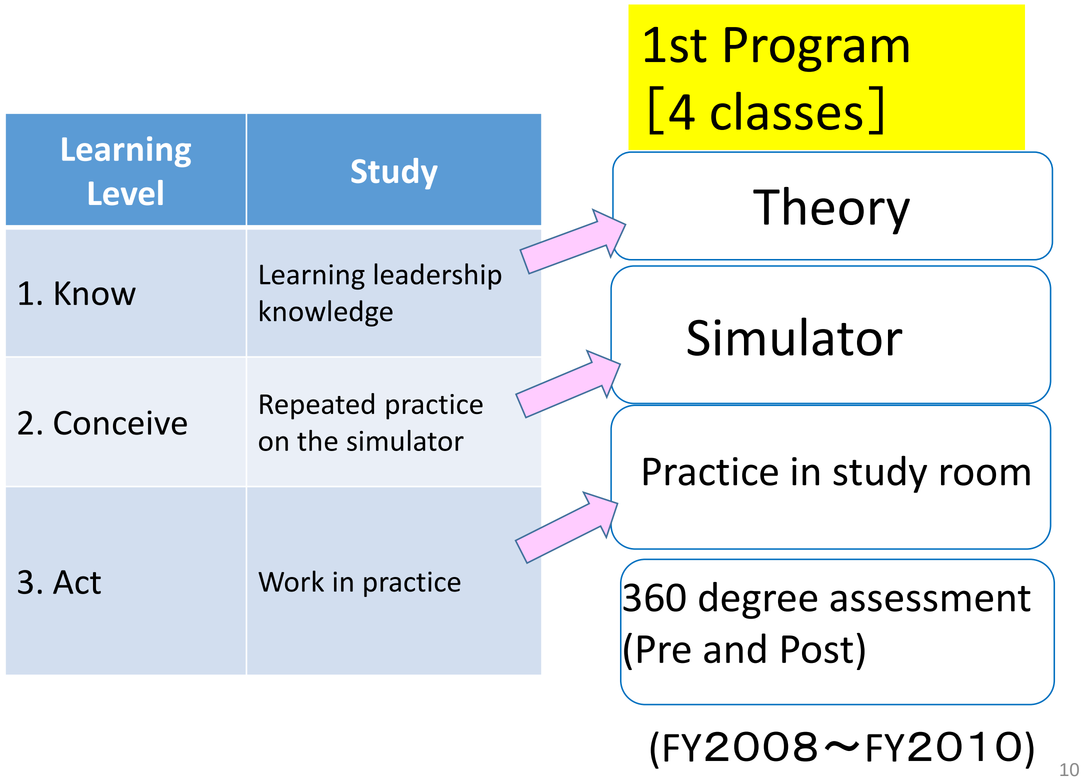

Figure 3. Feature of the 1st Program

4.2. Quality Improvement in Stage 2 （Program B）

Program B was conducted between the 2011 and 2012 fiscal years (Figure 4). We added repeated practices on roll play between simulation and real actions with the results of course evaluations from Program A. In role play students could practice with an actual person on simulated experiences in simulation. This lessened the gap between reality and simulation so that students were able to be less resistant to take leadership. Also, it provided practice in reading emotions of the other party through facial expressions and tone of voice. In terms of study evaluation, we conducted 360-degree assessment before and after the class. At the same time, we introduced Rubrics and learning portfolio so that students could easily achieve their goals and measure the degree of their own growth by themselves. Especially from learning portfolio, they became aware of the importance of communication in technical activities, and to positively operate research laboratories and seminar. We confirmed the level 3 achievement on knowledge, consciousness, and action in the study accomplishment levels.

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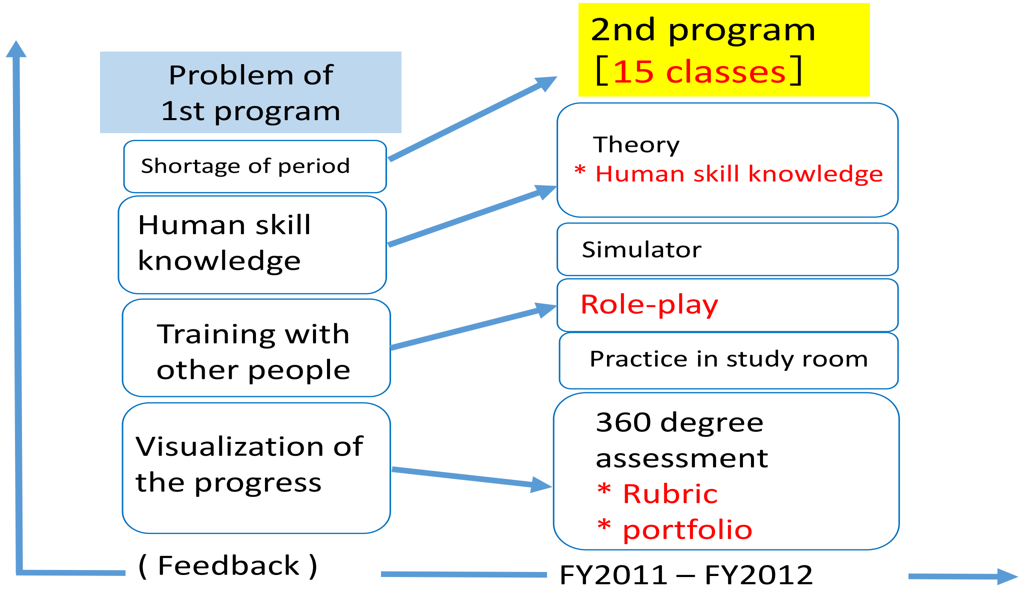

Figure 4. Feature of the 2nd Program

4.3 Quality Improvement in Stage 3 (Program C)

Program C was conducted in 2013 (Figure 5). With the results of course evaluation from Program B we realized that it would be necessary for students to get more chances of leadership action to achieve the level 4 "mastery". Therefore, we gave students such chances in Project Based Learning (PBL). Such PBL requires teamwork between students of multidisciplinary groups, and demands goal attainment. Therefore, PBL gives students challenging situations with tension and pressure that they do not have in research laboratories, seminars and lives. Moreover, as the team is composed of students of different disciplines, students are required to have communication skills. In order to promote mutual understanding toward the project thorough explanations and meaningful communication, they must expend more energy and pay more attention when relating with people of different disciplines than with those of the same discipline.

Utilizing all the chances in such situations, they practiced leadership actions. With the results of the evaluations given by the leadership assessment in PBL, a 360-degree assessment, and Rubrics, we confirmed that students gained knowledge, awareness, and achieved action levels. In addition, after finishing the course, students spontaneously took leadership actions, and some joined international PBL. Half a year after the course, we conducted interviews with students regarding the impact of this education program and PBL, and gave them emotional quotient tests focusing on emotional aspects of human relation skills. With the above assessment results we confirmed that their leadership skills were raised via the synergetic effect generated by this leadership education coupled with PBL. In particular, their human relation skills were raised, and they showed better actions in relationships. Thus, we confirmed the level 4 achievement, mastery.

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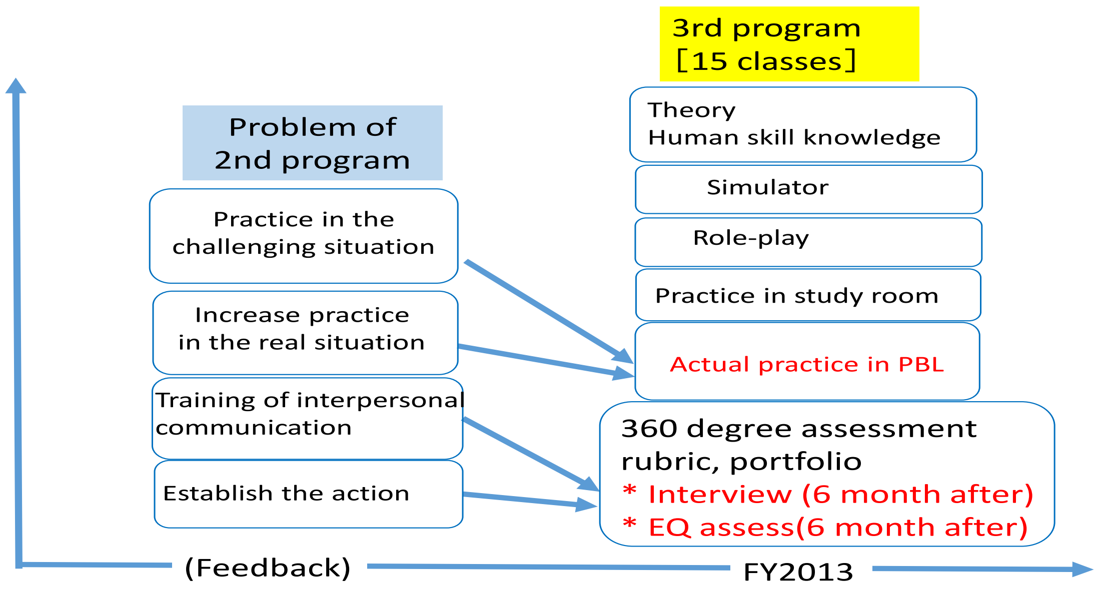

Figure 5. Feature of the 3rd program

5. Conclusion

With the goal of quality assurance of a class curriculum, we applied the PDCA cycle on leadership education on graduate students of engineering, resulting in seven years of continuously improved quality of the education program in which students achieved their learning goals.
In this cycle students acquired knowledge, utilized simulation, applied simulated experiences toward reality, and reflected on their real actions. Thus, this cycle led to the level 3 achievement to enhance transformation of action and even to the level 4 achievement, mastery of their new actions in leadership.

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Determining agility impact index and generating employee based questions to assess organizational agility

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Abstract

Agile software development has become more popular during last decades. Learning to be agile is not an easy task and requires some effort. The problem is that organizations don't know at what level of agility they are and what they need to learn in order to be more agile. Purpose of this research is to determine AII (Agility Impact Index) of organization domains and create algorithm for generating employee based questions. Result of the research is a list of AII for the organizations domains and subdomains. Determined AII is used by created algorithm to generate more specific employee based questions to enable better learning of current situation in organization. Results will be used by method ODA (Organization Domain Agility), method of improving organizational agility.

Keywords: *Agile, Organization Domain Agility, Agility Impact Index.*

1. Introduction

Agile software development is used by many Software Development Companies (SDC). At the beginning of agile software development there were different agile methods, for example, Extreme Programming and Scrum. Interest in agile development was and still is at very high level. It is possible that anxiety is not at such level as before, but it could be explainable with agile approach stabilization and availability of a high quality literature. And there is no doubt that mostly problems and solutions are described in literature, but the problem is, even if you read the available literature it does not guarantee that SDC is implementing agile methodology correctly and it will work as imagined. And the problem hides in fact that it is hard to put it all together. Companies which have greater financial resources are hiring agile experts to help them to adopt to agile software development and this leads as to the next problem, because agile experts are expensive and it is almost impossible to keep agile expert on stuff for a longer period of time. Transformation to agile software development does not happen instantly and might take even couple of years, depending on size of the SDC and the types of a projects. This transformation process is very specific for each organization and team.

There is a need for a method which can be used without usage of agile expert on daily basis. To deal with the problem a new method is proposed that allows to follow the process of a transition from traditional to agile development. This method allows to keep track on transformation and check the agility level of the organization at regular intervals. Solution proposed includes decomposition of the organization into agility domains, subdomains and attributes. Process of evaluation and improvement is implemented in method ODA (Organization Domain Agility) and is based on Scrum process [2], but it could be adjusted to work with other agile methods as well [4].

The main focus of the paper is to briefly introduce the method ODA and the concept of organizational agility and in more details describe Agility Impact Index (AII). AII is used by the method ODA and Question Generation Algorithm. To achieve the goal the following tasks have been completed:

- Concept of organizational agility is defined;
- Agility Impact Index is described;
- Agility evaluation method ODA is defined;
- Question generation algorithm is introduced.

This paper consists of 6 sections. The first section is introduction and describes the problem and the goals of the paper. Second section introduces concept of organizational agility which is used by the method ODA. Method

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ODA evaluates agility of the organization and is described in third section. Fourth section describes AII which helps to put weight values on domains, subdomains and attributes (DSA). Fourth section also includes AII values for the DSA. AII values are determined by the group of experts. The fifth section focuses on question set generation. Answers to questions in combination with AII values help to determine organization agility. The sixth section concludes the paper and gives brief outline of the future work.

2. Concept of organizational agility

Organizational agility is measurement which indicates how agile the organization is. This measurement is important for organizations and teams practising agile methodology. Agility is measured in scale from 1 to 10, where 1 is organization is not agile and 10 organization is agile. Measuring organizational agility is not a simple task as organization is a complex system and it is hard to decide where to start. Proposed approach splits the organization in smaller components called domains, subdomains and attributes (Fig. 1.), this way enabling evaluation of smaller components. Domains, subdomains and attributes are defined based on previous research [1] and main principles of Agile Manifesto [6]. Long path of determining organizational agility starts with defining domains, subdomains and attributes (DSA). Initial DSA is defined by researchers and agile experts, but can be modified for specific needs of the organization.

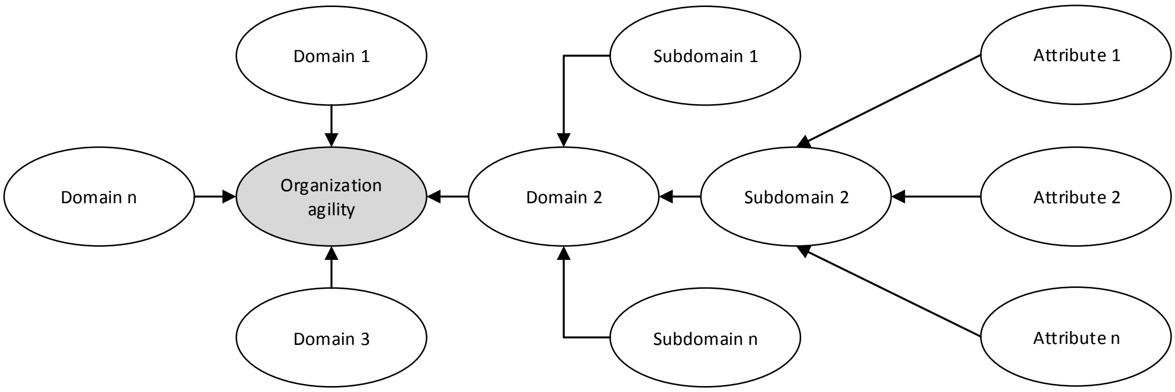

Figure 1. Organization agility concept

Initial structure of the DSA is described in chapter 4 together with Agility Impact Index (AII). DSA describes different parts of the organization, for example, top level domains are organization, productivity, quality, process and value. Organization domain defines common organization properties and processes which are at organizational level. Productivity domain defines properties of production team which builds the products. Each domain is divided into subdomains. Subdomains describe domain in more details. Subdomains can consist from other subdomains if necessary to logically describe some subdomain. The bottom level is attribute and it is the smallest descriptive element, for example, it can describe how big the agile team is and how the size of the team influences the agility. It is harder for agile team from 20 members to be as agile as team of 8 members. There are too many additional coordination processes for such large teams and all meetings will just take too much time to be effective. This is just one of the examples. As there are 5 domains at the moment and it is impossible to add figures for all of them in this particular paper, then it is decided to add only schema of the Productivity domain (Fig. 2). Productivity domain consists from 10 subdomains, such as, Knowledge management, Learning, Environment, Collaboration, Motivation, Team, Communication and Practice change management. Productivity domain deals with part of the organization where software product is built.

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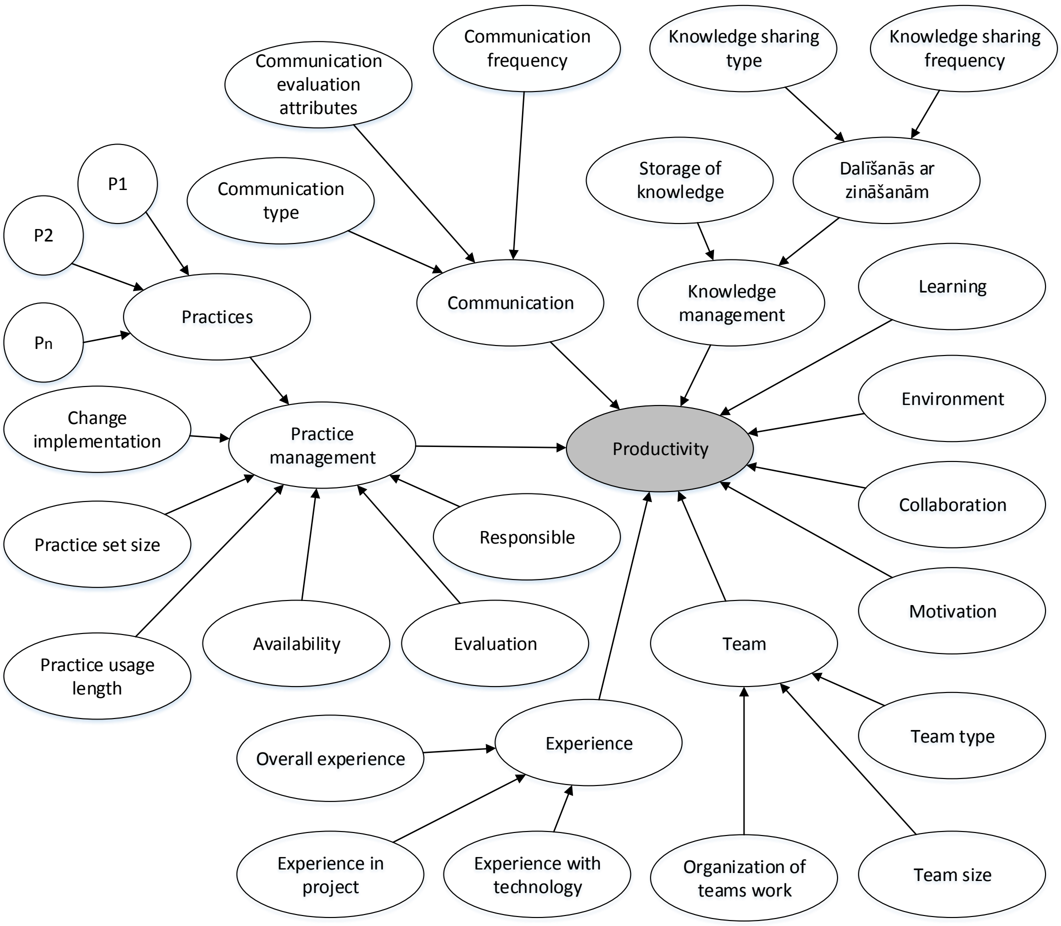

Figure 2. Productivity domain

Good agile experts can identify such problematic areas while evaluating the organization or the team, but the problem is they are too expensive to be on staff all of the time. There should be some method developed to help identify such problematic areas without involvement of agile experts at each stage of the software development.

3. Method ODA

Method ODA is the method of identifying organizations agility and its process consists of several steps (Fig 3.). Method can be used by organizations or teams which want to adopt to agile software development or are at the stage of transformation to the agile development. Method can be used by small agile teams or by big enterprises to improve their agility level.

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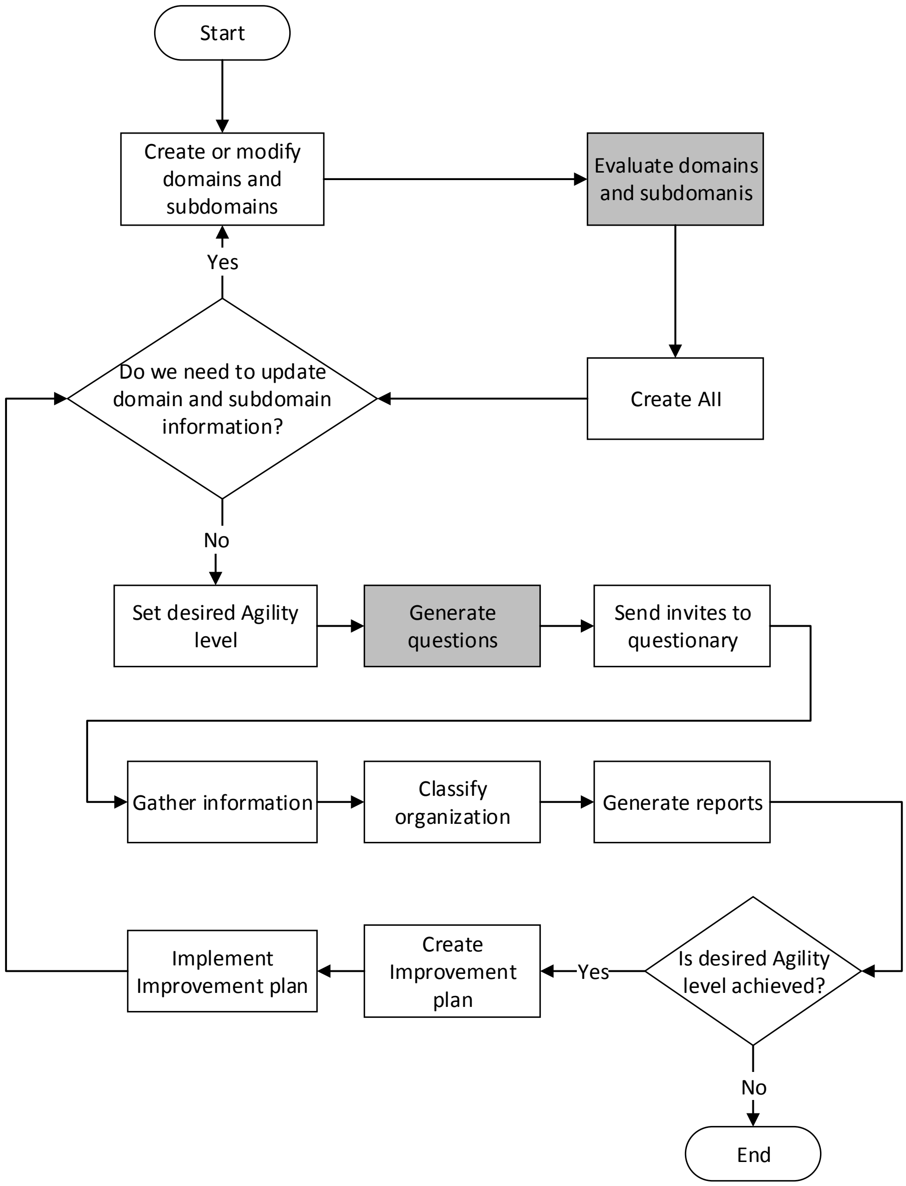

Figure 3. Process of the method ODA.

Simplified processes of the method consists of 11 steps:

- Creation or modification of domains, subdomains and attributes (DSA) is an initial step.
- List of DSA is evaluated using method Delphi or similar method.
- Data gathered in previous step is used to create a list of AII values for DSA.
- Desired level of organizations agility is set.
- AII values are used to generate set of questions. There are approximately 550 questions and only small set of them is used at each questioning.
- Invitations for questionnaires are sent to each employee involved in questioning.
- Information gathered from surveys is used to classify organization and calculate organizations agility level.
- Agility level reports are generated to show organization agility in structured way. Structured reports help to identify the problematic area.
- If it is necessary Improvement plan is created to increase the agility level.
- Improvement plan is implemented.

Agility level improvement cycle is repeated in scheduled periods. Frequency depends on organization and team, for example, some teams can perform evaluation cycle after each iteration, but some every second iteration. Number of questions also depends on the organization and team. It has to be kept in mind that were are about 550

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questions in total and larger number of questions gives more accurate result, but asking such amount of questions each time will stress employees and willingness to answer the questions will decrease.

In Fig 3 two of the elements are indicated in grey colour. The items in a grey colour are described in this research paper in more details. The process of assessing AII values of DSA has to be done at least once and repeated if the DSA configuration changes and it should be done by expert network. Generation of questions and survey processing is done regularly at defined time intervals. Organization can choose how often they would like to repeat the agility assessment.

4. Agility Impact Index (AII)

Agility Impact Index is a metric to evaluate each domain, subdomain and attribute (DSA). AII determines how one particular item of DSA influences overall agility level of the organization. To this point there are five domains, 130 subdomains and 548 attributes defined. Some method or systematic approach is needed to determine the AII values. AII for DSA is measured in the scale from 1 to 10 and is determined by the group of agile experts using method Delphi [3] or similar evaluation method where group of experts is involved. Such approach allows us to build the AII value tree (Fig. 4). Tree view of DSA values is helpful when organization is evaluated and its agility determined. Also tree view helps to identify specific part of the organization where some adjustments are needed after classification is made.

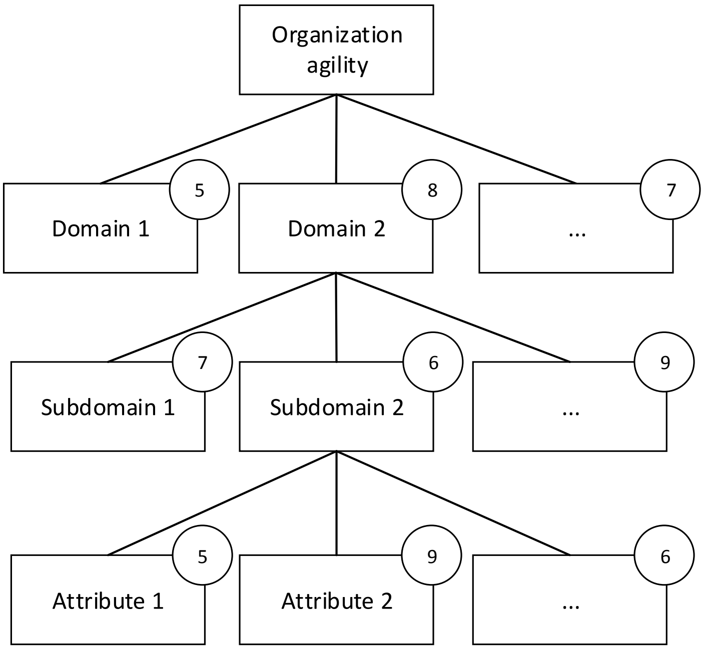

Figure 4. Sample AII value tree.

To gather the AII values network of agile experts were used. The group consisted of 20 agile experts with different levels of expertise (5-10 years). Two rounds of surveys were conducted to reach expert consensus on AII values. Top level domain AII values are shown in Table 1.

Table 1. AII values for top level domains

Domain	AII value
Organization	9
Process	9
Productivity	9
Quality	8
Value	8

As shown in Table 1, by expert opinion all top level domains impact organizational agility heavily. Productivity domain AII values are shown in Table 2.

Table 2. AII values for Productivity domain

Subdomain	AII value

Communication	10
Cooperation	7
Environment	8
Experience	9
Knowledge management	9
Learning	9
Motivation	9
Practice change management	6
Team	9

Expert opinion concerning Communication subdomain is very interesting, as in the context of the Organization domain it does not impact agility on the same level as in the context of Productivity domain where it is at the highest level.

Table 3. AII values for Organization domain

Subdomain	AII value
Communication	6
Experience	9
Goals	9
Learning	9
Process change management	5
Size	7
Team building process	7

Table 4. AII values for Quality domain

Subdomain	AII value
Agreements	4
Focus on excellence	7
Guidelines	7
Practice change management	3
Roles	3
Standards	6
Tools	9

Table 5. AII values for Process domain

Subdomain	AII value
Artefacts	8
Roles	9
Timeboxed activities	8

Table 6. AII values for Value domain

Subdomain	AII value
Metric change management	8
Portfolio management	7
Product management	8
Release management	8
Value delivery	9

Unfortunately only top level subdomain AII values are listed in this paper due to limitations on number of pages.

5. Question generation algorithm

Question generation is the part of the method ODA. The purpose of the questions is to identify organizations agility. One of the problems is that there could be too many questions to ask each time and some solution is needed to decrease the amount of questions. The Question Generation Algorithm is developed which helps to generate set of questions for each employee during each evaluation iteration. Organization and team makes decision how big the generated question set should be and this value can be changed between evaluation iterations. Bigger the set, faster the organization or team can get more precise picture on organizational agility, but it must be kept in mind that bigger questions sets take longer time to answer and usually employees do not like it and it can lead to willingness not to answer questions at all.

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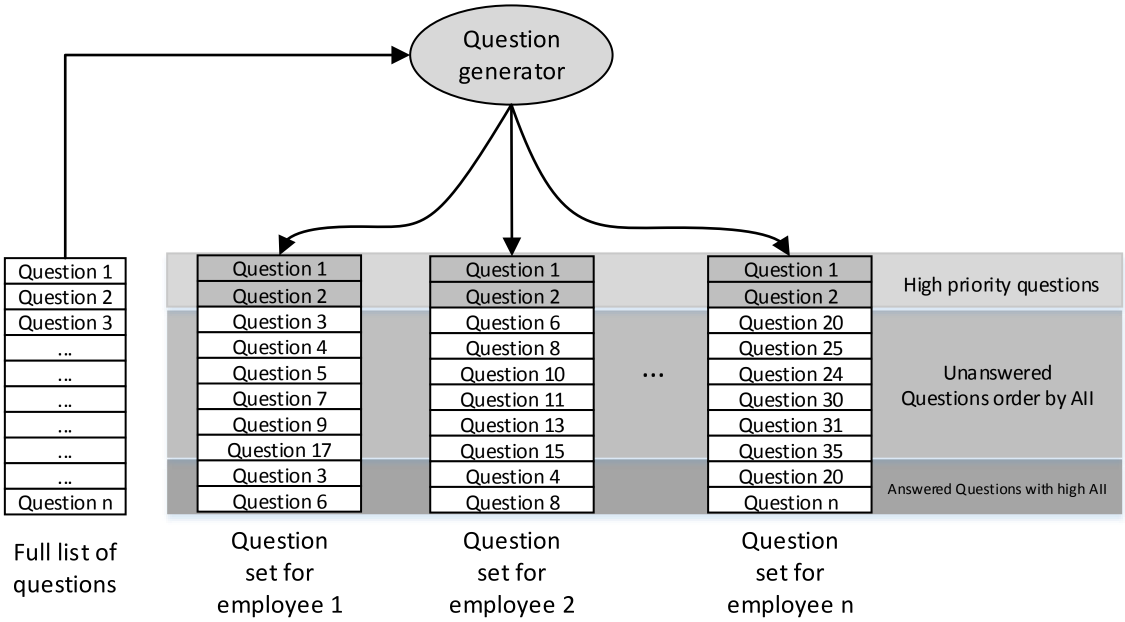

Figure 5. Question set generation.

Generated question set consists of 3 types of questions (Fig. 5.):

- High priority questions – questions marked to be answered during next assessment period. This type of questions is useful when organization or team wants to get quick feedback on things they start to implement, for example, new practice or process. In such cases it is important to get information from as many sources as possible.
- Unanswered questions ordered by AII – questions with highest AII value are asked first and then ones with lower AII values.
- Answered questions with high AII – questions with high AII value are asked more frequently even if they have been asked before. This helps to keep track on items which influences the agility level the most.

The approach of splitting the questions in sets helps to get overall information fast without overburden employees and additionally the advantage is that information comes from different sources and is more trustworthy than information from just one source.

6. Capabilities and limitations of the method ODA

Every method is built to serve some particular purpose and can be used to solve specific problem. Purpose of the method ODA is to help identify problematic areas of the companies. The company should be in the transition process to agile software development or practicing agile software development. Mostly the method should help in transition process. Organizations already practicing agile would benefit by keeping pulse on the quality of their agile software development. Method ODA is not intended to be used in organizations practicing classical approaches such as waterfall.

Default DSA configuration of the method ODA is developed for method Scrum [2]. It is easily noticeable in the Process Domain of the DSA that all evaluated processes are Scrum based. AII values are defined for Scrum based processes as well. It is possible to modify the DSA to suite other agile methods, but it will require to get new AII values for the newly created DSA. This step would include creation of agile expert network and re-evaluation of the AII values. It could be time and money consuming process and not all the organizations would like to handle it. Recreation of the DSA also requires high quality knowledge about the agile methodology and usually organizations does not have appropriate expertise.

Size of the organization does not influence heavily usage of the method ODA while each team of the organization is evaluated separately. It is important to notice that in one organization each team could have different agility level.

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7. Conclusion

Evaluation of the organization agility is not simple. To evaluate organization agility it is recommended to split organization into smaller components (domains, subdomains and attributes - DSA). This approach allows to evaluate smaller components and determine organizational agility. Each item of the DSA is evaluated and Agility Impact Index (AII) is defined for each item. AII defines how particular element of the DSA influences the agility of the organization. In context of this paper evaluation method Delphi is used [3] to evaluate five domains, 130 subdomains and 548 attributes. Usage of agile expert network in this case is essential, but also problematic. Agile experts have experience and knowledge, but it is hard to get them together. Online survey was created and two rounds of surveys completed, before result was achieved.

Determining AII is the part of the method ODA. Method ODA defines the process of determining organization agility. Two main components of the method ODA are Question generator and Classification algorithm. Purpose of the Question generator is to generate set of questions for each employee. Small question sets makes it possible to do agility assessment more often without overburden employees. Question set consists of three types of questions: High priority questions, Unanswered questions ordered by AII values, and Answered questions with high AII. AII values in the combination with gathered data are used by classification algorithm. For classification algorithms such as FOIL [5] can be used.

Method ODA is not tested at this point, but at the time of expert questioning which was done to determine AII values, the interest in the method and classification was high and appealing for agile experts. Agile experts are waiting for method testing results and are willing to participate in further work.

Next step in this research is to test the method ODA in several enterprises to gather some additional results and adjust DSA if necessary.

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Indicators of economic development of technologically advanced countries

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Abstract

Studies of the dynamics of most countries make it possible to assert that the development of the largest countries - technological leaders in modern conditions is characterized by a certain constant. It can be considered as "current macroconstant of development." The article demonstrates the fact of its existence and justifies statement that "current macroconstants of development" can and should be orienteers for strategic development for all countries pretending to equal economic and political relations with the technologically leading countries.

The paper identifies conditions under which the group development macroconstant appears, evaluates particular values of macroconstants in different countries and shows advantages of long-term growth measure in the absolute values of the annual income per capita of the country change rate in comparison to other indicators.

Conclusions in the work are based on the analysis of long-term data of total GDP, GDP per capita and their derivatives. Analysis has been done by using quite well known econometric methods - correlation, regression and cluster analysis.

Practical importance of the results is characterized by opportunity of their use for long-term (15 years or more) forecasting and strategic planning of growth rates, both for companies and countries within industrial and economic policies.

Keywords: *firm, forecasting, development, potential, a constant pattern, clustering.*

1. Case history

History of coexistence of different countries is characterized by a continuous rivalry. In the last half-century, it has moved into the sphere of technological progress. Long-term leadership of a country in the technological race is provided by high long-term growth of its development. Characteristic of this development, in the case of clarifying of its stability at significant period, can be an important benchmark of development for firms in the competitive rivalry.

Analysis of the economic development dynamics of major developed countries suggests that over the next 15 - 20 years their development potential can be characterized by some quantitative indicator. This is an average value of their growth rates, which, in specially identified constraints, is independent on time.

Our research of dynamics of the largest countries - the world's technological leaders, allows advancing and defending the following statement. *After reaching a certain level of development, conventionally, the entrance to the post-industrial period, acceleration of development of large technologically advanced countries is characterized by some constants. They are conveniently called "current macroconstants of development."*

Judging by the available sources, the concept of "macroconstants of development" now, is not used in the theory [7, 8], or in the practice of industrial policy [13; 14; 15; 16]. Indeed, there is a reliably known inverse characteristic of countries - a high rate of instability of their development. Verifying the existence of instability is very simple. It is enough to look at the dynamics of interest growth rates changes of aggregate GDP or GDP per capita of any of the developed countries. For example, the dynamics of the annual GDP and GDP per capita in Japan between 1961 and 2010 (Figure 1) shows not only the changes at times of percent growth rates change in GDP from year to year, but also a constant declining trend of annual percentage growth.

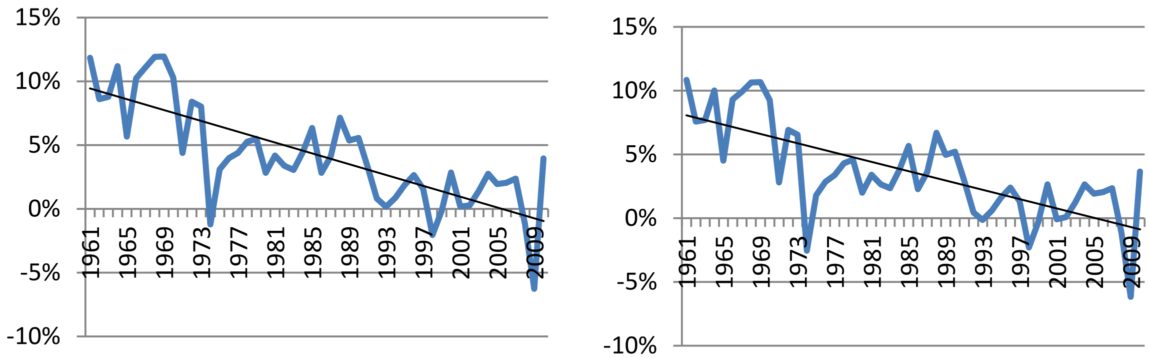

Figure 1. The tendency of interest growth rates change of aggregate GDP (left) and GDP per capita (right) in Japan.

However, it can be stated that conceptually similar to presented in the article studies were conducted by Anglo-American economist Angus Maddison [10]. He showed that there are two different trajectories of development. The first trajectory - A - characterizes countries that grow with a constant low average annual rate, but when considering the growth in large periods, the result is high.

The second trajectory – B – indicates that there are countries that are growing, making the sometimes serious leaps, but at the same average rate of growth is not high.

In this situation, information that the economies of several countries characterized by some measure of development that does not change over a sufficiently long period will be of a special interest. That is a characteristic that can be called current macroconstant.

2. The idea of a hypothesis and test conditions

We assume, that microconstant ***is a statistically not changing for a long enough period (in 15 -40 years) characteristic of the country development.***

The existence of macroconstants is identified by value of the correlation (determination) coefficient between the tested factor and time. If the correlation coefficient is statistically equal to zero can be argued that the value of the test factor (Y) is independent on time (X).

Evaluation of *in*significance of determination coefficients is checked by the value of Student's T-criteria. The empirical values of T-statistics were calculated for all the considered dependencies and comparison showed that T <Tcrit. So, the null hypothesis was confirmed, that the correlation between Y and X is absent.

Usually, economic studies aim to find the dependence of some economic characteristics on time. The problem solved in this case is inverse. It should be shown that at certain stages of the global technological development in certain countries could occur a characteristic, which does not depend on time.

In the process of searching of current macroconstants most common performance indicators in most countries of the world[1] were studied. Changes over the time were examined for such macrocharacteristics of development as the absolute size of GDP, its growth, the percentage of annual GDP growth, as well as all of these characteristics per capita and per person employed in the country's production. There are nine characteristics in total.

In order to prove the existence of current macroconstants in our chosen group - the major developed countries of the world, there have been implemented three stages of analysis.

[1] Static data taken from the site of the World Bank – http://data.worlbank.org/indicator/...

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At the first stage, we clarified which of the nine studied characteristics can claim the status of macroconstants of development and what criteria should be taken to select countries where development is characterized by current macroconstants.

At the second stage, it was shown under what conditions or restrictions current macroconstants arise.

At the third stage, it was shown that current macroconstants, identified based on the previous period, completely, or with a small correction, is stored further.

At the first stage of the analysis, firstly by visual inspection of the development dynamics graphs, all nine macro development characteristics outlined above have been tested. In total more than 200 countries were tested. As a result, three most interesting candidates were selected. This is the percent of GDP growth - as the most commonly used measure of macro development, the absolute value of GDP per capita and the value of the absolute **growth** of GDP per capita per year.

One of the few arguments in favor of the constants of macroeconomic development existence can be a persistent increase in the percentage of USA GNP for sufficiently large historical period. So, for almost hundred years from 1890 to 1986 USA GNP growth is well described by a curve with a constant percentage growth per year - 3.2% [5].

However, statistics show that the leading economies of the world are not capable to maintain a constant percentage growth rate on a long-term time interval. The modern practice of the major developed countries, in most cases, demonstrates that the interest rates of growth are significantly reduced over time (for example, after a wave of industrialization). This is evidenced by the experience of Japan, Great Britain, France, and Germany (a typical example shows in Figure1).

The second indicator: *absolute value of GDP per capita* - is closely linked to the value of *time* and, therefore, cannot claim to be a non-changeable with time constant.

Last contender for the current macroconstants of development role is ***an absolute increase in GDP per capita.*** Studies have shown that this indicator could claim to be the current macroconstant, but under certain conditions.

The second phase of the analysis determines under what conditions or criteria of selection current macroconstants of countries development appear.

For the selection of the countries in which macroconstants of development may emerge among all countries in the world (214 countries), three criteria were used.

The first selection criterion limits the minimum size of the country population. According to our empirical evaluation, this boundary is 3,000,000 people. This number, also, is close to the minimum population of the leading countries of the world, which are included in the annual statistical and analytical reports of the US Bureau of Labor Statistics (BLS). Thus, the minimum population for all countries included in the report of the BLS 2011, equals to 3.4 million people (Ireland). Taking a small reserve and rounding down to a million, we get a boundary of at least 3 million people.

The second criterion selects the countries included in the "post-industrial period" of development. Justified in [1][2] the lower boundary of the "post-industrial period" beginning for a country is to achieve values of real GDP per capita of 15,000 in constant 2005 US dollars. This boundary is considered *necessary, but not sufficient* to ensure that the country has entered a "post-industrial period" of development.

[2] In article [1] it was shown that in all countries, the level of well-being which is higher than 16 - 20 thousand dollars (PPP) per capita (in dollars, 2005), the ratio of the GDP obtained by the exchange rate and purchasing power parity, is less 1. Moreover, the difference in the values of GDP is relatively small, about 20%. And in all countries, the level of welfare is lower than specified, the ratio of the two values of GDP significantly greater than 1, and they differ from each other ten times stronger. Analysis of the causes of the manifestation of these trends leads to the conclusion that they are caused by the transition countries with a GDP higher than 16 - 20 thousand dollars per capita in the new technological order, in other words, in the post-industrial period of development.

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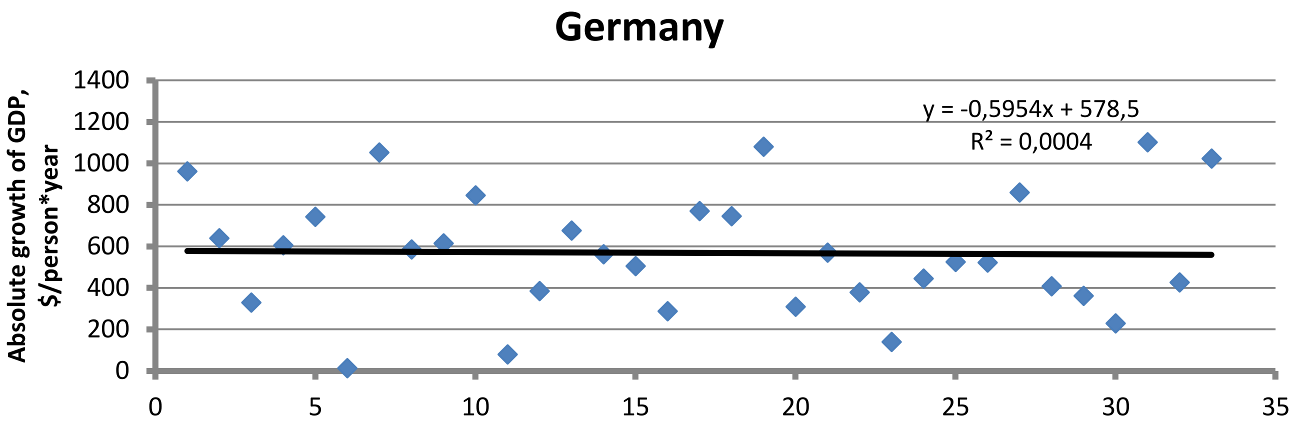

Figure 2. GDP per capita growth in Germany during stable economic development periods (1969 -2011). (Temp.=0,111 < Tcrit.= 2,744; insignificant with 99% probability)

The third criterion selects the countries included in the "post-industrial period" of development for a long time - not less than 15 years ago.

2. Analysis of the results of the research indicators

After applying the above criteria to all countries of the world, it turned out that for the further consideration remained 13 countries: Australia, Belgium, Canada, France, Germany, Greece, Italy, Japan, South Korea, the Netherlands, Spain, UK, USA.

In order to isolate a period of stability (normal) development from the entire set of data economic crises and stagnations as well as three years with the highest rate of economic growth were excluded.

A typical graph of the linear approximation of the absolute growth of GDP per capita with time in a stable economic growth shows in Figure 2. The figure shows the dependence, or rather the lack of dependence of the absolute growth in GDP per capita with *time counter* (consecutive years of stable economic development). This is evidenced by statistically insignificant by t-test value R^2.

Visually, theoretical regression line in some cases shows an increase in the growth rate of GDP per capita. However, strictly statistically conclusion on the increase of GDP growth rate over time is not confirmed. This is also evidenced by statistically insignificant by t-test value R^2.

Similar results were obtained for all 13 countries.

Almost zero value of the coefficient of determination R^2 allows us to conclude that ***for countries that meet the three above defined criteria of selection, the absolute increase in per capita GDP in normal economic situation does not depend on time.*** That is, because of the second stage of the analysis can be stated that ***in the post-industrial period, only in large countries and only in ordinary conditions constants of macroeconomic development are manifested.***

We emphasize, that in this article demonstrates the existence of macroconstants, that arise, firstly, in the major advanced countries of the world, and secondly, when the crises years and three years with a maximum speed of development are excluded from the array of information.

However, it should be mentioned that in most cases, macroconstants appear without exception of crises and the most effective years, but not as clearly.

The task of the third stage of the dynamics of the developed countries analysis - to show, that macroconstants, identified in the previous years in initial form or with a small correction are stored in the following. This task is solved by a comparison of the USA macroconstants identified for two consecutive period of 25 years (see figures 3, 4).

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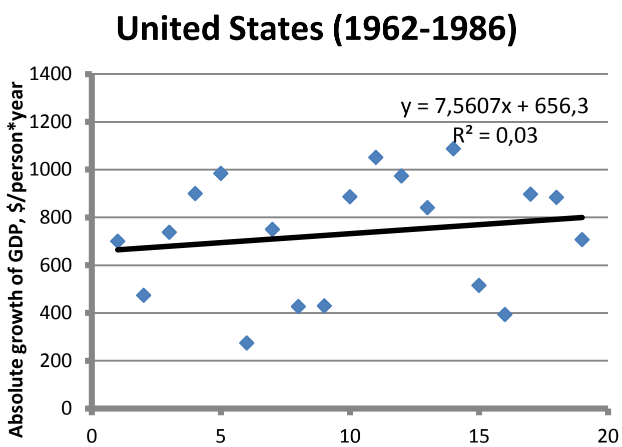
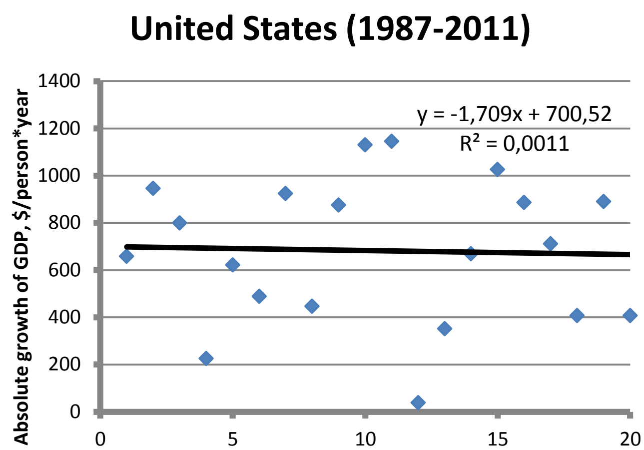
The rate of development of the country, formed in 1962-1986 which is 732 dollars / person per year (see figure 3), seems to be a good forecast of development rate for the next 25 years. Forecast for such a long period is sufficiently accurate.
The actual average growth rate in the subsequent period - 683 USD / person per year (see figure 4) differs from the rate of growth in the previous (732 USD / person per year) by 6.7%.





Figures 3, 4. The GDP per capita growth in the US for 25 years in an initial period of stability economic development (left) /Temp.=0,725 < Tcrit.= 2,898; insignificant with 99% probability/ and GDP per capita growth in the US for 25 years in a follow period of stability economic development (right) /Temp.=0,14 < Tcrit.= 2,878; insignificant with 99% probability/

It also means that ***under normal conditions of post-industrial development a constant that characterizes the long-term development potential of the major developed countries arises.***
The table 1 shows the values of current macroconstants of developed countries, measured in three time periods - for the entire period of post-industrial development in the first 20 years after achieving a period of post-industrial development and for the last available 20 years after the period of post-industrial development.
In the accepted interpretation of the concept of "current macroconstants of development», we can say that this indicator quantifies the strategically important characteristic of the country's economy. In other words when having a high value of current macroconstant a given country is able to efficiently develop during a long period in any market fluctuations. In addition, vice versa with low value of current macroconstant the country cannot ensure high growth rates even under favorable circumstances.
Moreover, due to the fact that the lion's share of the country's GDP is created by firms, management of companies in terms of hard, and most importantly, dynamic competition, both at domestic and global market, gets in the form of current macroconstants a clear development guideline. If the development pace of the company is lower than current macroconstant, i.e., below the national average, the firm will lose the competitive battle. If it is higher, the firm assures its prosperity and stability in the market.
That is an objective benchmark that firms could use for a strategic assessment of its competitiveness and can serve as a long-term constant of macroeconomic development of technologically advanced major countries of the world.
Current macroconstant of the country is a kind of average indicator of all its businesses development. Therefore, if a company wants to remain successful and competitive, it is important to follow the paces of development not lower than average. In addition, the identified values of current macroconstants can and should be an essential reference point for the industrial policy of technological development, or aspiring to this status of any country, regardless of its size.

Table 1. Current macroconstants of major developed countries.

Country	Current macroconstants, 2005 US $ per cap.		
	All post-industrial period	First 20 years of post-industrial period	Last available 20 years of post-industrial period
United States	639.8	505.4	683.7
Japan	555.6	611.0	531.3
Germany	568.4	588.7	561.7
France	412.5	406.7	400.8
United Kingdom	601.0	523.4	696.3
Italy	435.6	499.2	422.7
Korea, Rep.	837.4	837.4	837.4
Spain	468.4	477.2	461.0
Canada	549.3	515.6	591.5
Australia	514.7	477.9	560.3
Netherlands	592.8	571.7	615.3
Belgium	500.6	516.7	500.0
Greece	462.5	462.5	462.5

In the framework of this approach, we tested a hypothesis that the cluster or a group of similar countries will have its own macroconstant.
Assessment of the hypothesis of independent current macroconstants origin within the group of countries was made using the methods of cluster analysis. In test mode, the clustering was performed on the same set of 13 advanced countries, highlighted above.
We tested the hypothesis that under certain combinations of values of the mean absolute increase in GDP per capita and the number of years of post-industrial period (separate clustering was also considered with a factor of population) groups of countries with close to each other current macroconstants can be distinguished.

To test this hypothesis we used the standard hierarchical methods[3]:

1. Single linkage. Also known as the "method of a nearest neighbor".
2. Complete linkage. Also known as the "method of a distant neighbor."
3. Pair-group method using arithmetic averages.
4. Pair-group method using the centroid average.
    - Unweighted.
    - Weighted (median).
5. Ward's method.

Evaluation of homogeneity of the studied sample and dividing them into clusters was made using a Euclidean[4] metric.

[3] The above methods are available, for example, in the Statdraphics statistical package.
[4] **Euclidean distance** between **p** and **q** is the length of the segment $\overline{\boldsymbol{pq}}$. In Cartesian coordinates, if **p** = (p1, p2, ..., pn) and **q** = (q1, q2, ..., qn) two points in Euclidean space, the segment length of **p q** is equal:

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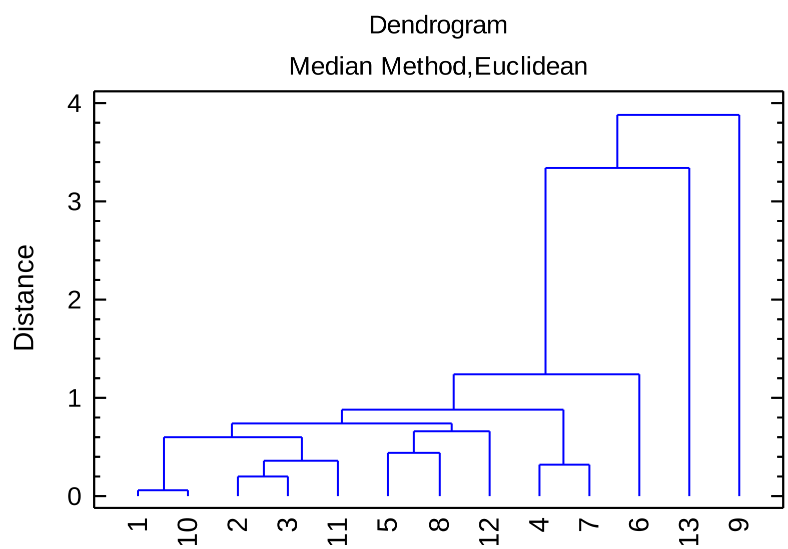

Figure 5. Clustering with population consideration (3σ = 3,7)

In all cases, the criterion for division into clusters is the rule «3σ». That means that the separation of the clusters occurs at the 3 standard deviations from the number of all the distances between the objects. If the distance between the object does not exceed three standard deviations, they belong to the same cluster, otherwise - different.

However, none of clustering methods gave, *at first sight*, a satisfactory result. The countries just joined consecutively to each other in the dendrogram, and the rule of «3σ» combined them into one group and one "omitted point" - South Korea. The example of dendrogram or icicle diagram shows in Figure 5.

Vertical axis of figure 6 shows the distance between objects. Connecting lines in the first step show, which of the objects are closest to one another ("the letters ∏"). In subsequent steps, the same lines attach the next nearest objects to the ones that are already connected. This occurs as long as last object of observation will be attached to one figurative cluster.

The abscissa presents numbers of countries participating in the process of clustering:

1) Australia; 2) Belgium; 3) Canada; 4) France; 5) Germany; 6) Greece; 7) Italy; 8) Japan; 9) The Republic of Korea (South Korea); 10) The Netherlands; 11) Spain; 12) United Kingdom; 13) United States of America.

The fact, that the countries are not divided into groups, most likely points on their real uniformity. The total value of intra-group macroconstant - 540 USD.

3. The main results of the research indicators

Realized studies allow stating the following general conclusions:

Firstly, we can say that the development abilities of technologically most advanced and largest countries in the world, at least at the stage of (contingently called) post-industrial development, are characterized by a specific constant of development: the growth rate of GDP per capita (USD /person per year).

Secondly, there is only one group of major advanced countries, the development of which in ordinary conditions is characterized by intra-group macroconstant.

Third, the group constant of countries development - the world's technological leaders can and should become a benchmark for strategic development of both countries and companies at current period. Moreover, for companies it should be a lower limit of normal development.

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Searching for an Online Marketing Effectiveness: The Potential for a Small Business Sector

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Abstract

The paper describes the essence of online marketing for small businesses in terms of using the advantages of its tools and methods for better promotion and improvement of general business operations. A research involving small businesses in Croatia was done in order to define what tools and methods have the potential to increase companies' sales and advertising and whether they are used effectively. Despite a variety of elements in the online marketing that can help small businesses in Croatia in their promotion and sales growth, frequently an online marketing strategy is not appropriate which causes poor short-term or long-term results. Such results discourage further use of online marketing tools and consequently underestimate its potential for small businesses. Changes brought by new technologies represent a big opportunity for marketing specialists to take a strategic role within the company. Such a role assumes recognizing the marketing potential of the new technologies, building stronger relationships with consumers and discovering new business opportunities through technology. The main challenge for marketing professionals, as well as scientists is the dynamic character of the Internet as a technology, market and a social phenomenon. The goal of this paper is to propose an optimal strategy for small businesses in Croatia that may guarantee the success of using online marketing tools today.

Keywords: Online marketing, technology, small business, strategy

1. Introduction

An increasing number of small businesses around the world use different online strategies. These strategies are linked with additional variables such as the size of the country/region, population density, mobile telecommunications and internet penetration rate. Due to different levels of internet marketing penetration of individual contries, most of the available numeric and statistical data about the online marketing strategies comes from the USA, while such information and data accessibility in Europe and especially Croatia, is not as elaborate. In order to decrease such differences in data, this paper introduces the new online marketing statistics for Croatia and searches for an online marketing strategy model that holds the strongest potential for the small business sector in Croatia.

The key factor for online marketing success is the total online presence. [1] It emerges from the combination of high quality content platform, well positioned Search Engine Optimization (SEO) tools, efficient use of email marketing, interesting social media marketing, online advertising as well as the analysis and conversion, one of the most important aspects of marketing. Online marketing is efficient for all kinds of products and services, but it provides most efficient results with those products and services suitable for online purchase. The main benefits of online marketing are costs, measurability, content formating, targeting, coverage and speed. [2] The advantages and efficiency of online marketing increases if its tools and methods are systematically integrated and used.

There are different approaches, methods and tools in online marketing that can help small businesses build their promotion and sales, but the major challenge in Croatia is the negative attitude towards online marketing caused by poor online marketing strategy. [3] For this reason, the paper examines small businesses in Croatia and focuses on finding an optimal strategy model based on the influence of certain online marketing methods on the particular purchasing process phase.

2. Implementation of the cycles and methods into a strategy model

2.1. Purchase cycle phases

Each potential purchase is positioned within one of the three phases of the purchasing process, and that is awareness, evaluation and purchase itself. The following table shows customers' profile and the description of each of the following phases:

Awareness phase	Evaluation phase	Purchase phase
The meaning of the first phase is to stimulate people to start thinking about the problem/need and make them interested in getting more information.	*Customers are profiled as individuals aware of their problem/need who are now actively looking for the information that brings the solution.*	*This last purchasing process phase has the smallest number of customers involved because they now know exactly what they need and are interested which company can provide it.*

Table 1: Purchase cycle phases

In order to create successful online marketing strategy, it is important to know both the customers profile as well as their position in the purchasing cycle because an appropriate channel can be selected and used accordingly.[4]

2.2. Method classification

Internet is a communication tool that enables everyone, as well as companies, an efficient communication targeted toward the particular market segment. The tools and methods that are typically used can be divided into ones whose goal is to bring the potential customers on the website for the first time (advertising), and those that stimulate purchase in order to fulfill a certain goal (buying/selling). Therefore, the principal online marketing methods are online advertising and online sales promotion. [5-8] Online advertising includes search engine marketing (Search Engine Optimization and Google Adwords search), social media (Facebook, Twitter, Linkedin..) and online display (Google adwords display, buying direct banner ads). [5,6] Online sales promotion include the web sites (the key sales tool), email marketing (for the direct communication with customers) and content marketing providing the information that positions the company and pushes the customers towards the end of the purchasing cycle). [7, 8]

Internet Advertising Methods	Sales Promotion Methods
search engine marketing	*website*
social media	*email marketing*
online display	*content marketing*

Table 2: Online Marekting Tools and Methods

3. Research and Results

For the purpose of this study, 50 small businesses in Croatia have been surveyed. The goal of the online survey was to find out if they are satisfied with online marketing, what type of online marketing do they use and how it influences their business.

There are a few key results from this research that form a base for an effective online marketing strategy proposed here. As it is clear from the figure 1, most of the firms had expressed the positive impact of online marketing on their business. 62% of the total number of surveyed firms have expressed satisfaction with online marketing usage (grades 3 and 4), while the remaining 38% are not satisfied (grades 1 and 2).

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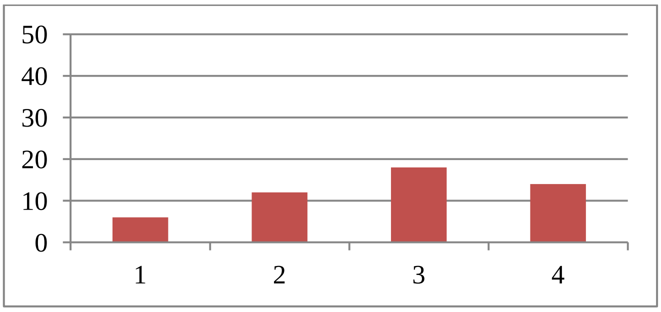

Figure 1: Croatian small businesses' level of satisfaction with online marketing

Figure 2 shows which tools and methods are most frequently used by the surveyed firms in their online marketing efforts. The highest percentage (75%) of surveye small business sector firms in Croatia are using Email for direct communication with potential customers, but there is also a significant number of firms that use websites (69%) and social networks (53%). According to such results, it is possible to conclude that Email marketing is active throughout the entire purchasing cycle, while the website is the main tool for sales promotion and social networks are being used as the main online advertising resource in order to better target the potential customers.

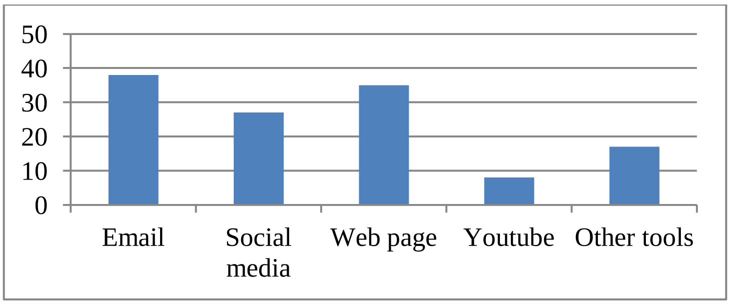

Figure 2: Most frequent promotion channels used by Croatian small business sector

Figure 3 shows the power of Facebook as the most popular and most influential social network in Croatia which makes it a central social network of the proposed online marketing model.

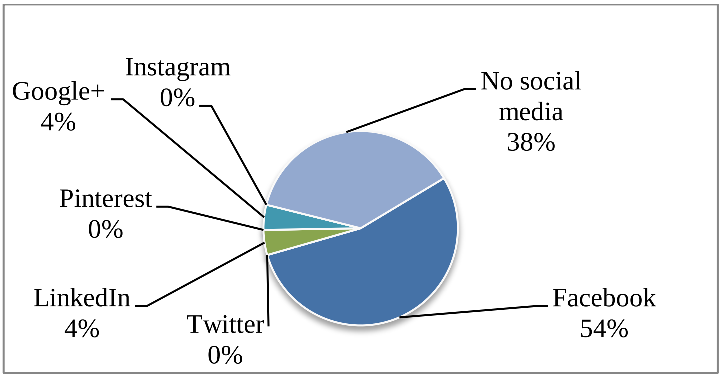

Figure 3: Social networks used by Croatian small business sector

Majority of the surveyed firms agree that without online presence small businesses today, both in Croatia and worldwide, cannot compete, let alone be leaders in their business segments. This is confirmed by the fact that over 80% of internet users go to Google.com on daily basis in order to find products or services that they need.[9]

The research done for the purpose of this study reflects the current online marketing situation of a small business sector in Croatia. The results clearly suggest that the fear of using different online marketing tools and methods

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is still present due to insufficient understanding of the online marketing. Although all the surveyed firms are familiar with websites, emails, social networks and other tools that help firms in their promotion and sales growth, only a small number use each tool to their full potential. Due to increasing number of competitors, this represents a serious problem for the small businesses because if they do not take their online marketing use to the higher level, soon the middle and large companies will take over their customers and clients only because they are more known, larger and popular.

Future of online marketing opens up many opportunities, but also many changes that may negatively influence the firms in Croatia. The research reveals the growing number of firms that are using Google AdWords. This trend will be continued in the near future which means that reaching an online marketing strategy effectiveness is going to be more difficult due to an increasing number of competitors. Google AdWords campaigns or websites are one of the most difficults forms of marketing because of the different aspects that they are combining. On one hand, that is the technical aspect of online marketing which means that program developers are a must because they enable the system to function. On the other hand, designers, copywriters and marketers are also needed because they make sure to bring the right decisions and continuosly work on optimization of each online marketing aspect.This trend will be continued in the near future which means that reaching an online marketing strategy effectiveness is going to be more difficult due to an increasing number of competitors. Being the most influential advertising service, Google Adwords (GA) will also be used in the proposed online marketing strategy model.

4. Croatian small business optimal online marketing strategy proposition

An optimal online marketing strategy includes advertising and sales promotion effectiveness followed by quantified results and accessing statistics such as number of visits, trends in traffic and revenue. In addition to tracking and analytics, in order to get an insight into customer behavior and better target their customers, it is important to detect customer’s phase of the purchasing cycle and then implement appropriate channels for communication and promotion. [10]

Figure 4 below shows the implementation of different online channels which affect particular points of the purchasing cycle.

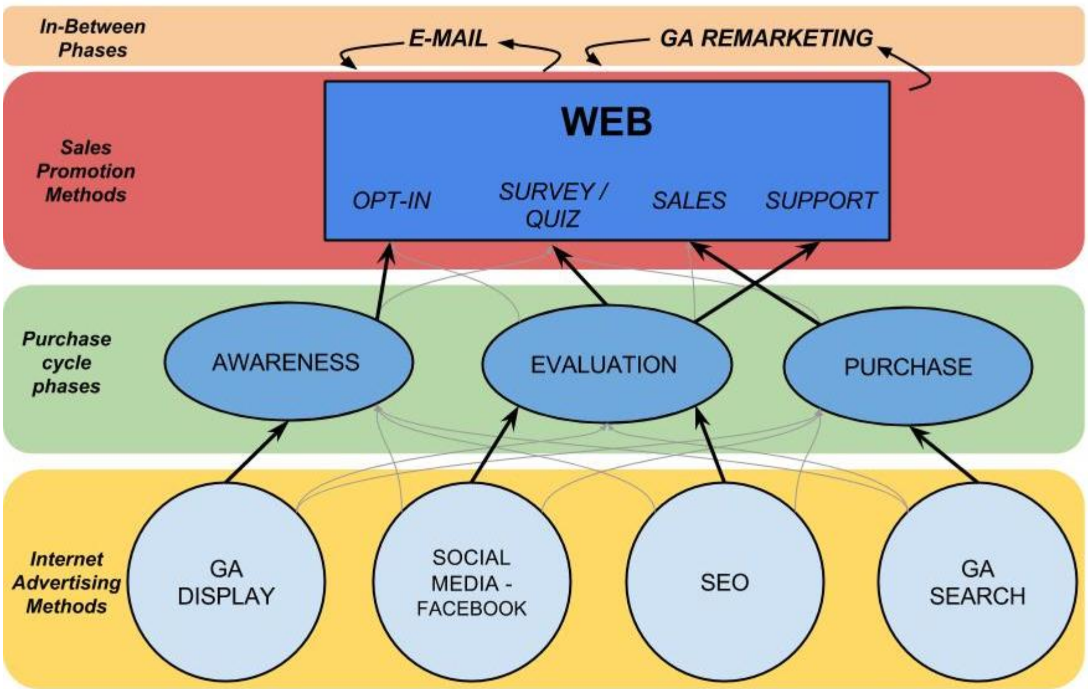

Figure 4: Proposed Optimal Online Marketing Model

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We will start from the first to the last phase of the purchasing cycle of a potential customer in order to explain which methods and tools are inserted to influence a particular phase.

4.1. Awareness phase

In this phase, the major promotion channel is GA Display, which is the ad shown on the website with specific content where the potential customers are getting the advertising messages while searching particular websites linked to specific products or services. This tool is used here because it adjusts well to the next, so-called awareness phase. It is possible to show adds to particular stakeholders that are precisely segmented according to certain demographics or other characteristics. It is good to target websites with similar content by putting an ad that provides solution to the problem or satisfaction of the need.

When a particular target group is approached through the ad which is in the focus of their interest, they click on the banner that directly takes them to an opt-in landing page of a certain website. At this landing page it is important to offer content that is providing information and building trust of the customers. For this reason, it is advised to make a good quality ebook that can be uploaded for free instead of an email. The point of this process is that customers get the feeling of the content importance which may help them find the solution for their problem instead of getting emails. This also enables firms to gather customer database that helps further develop their business through emails and remarketing. In this phase, the customers are profiled as still not particularly interested in a certain product or service so therefore it is important to offer some standardized information that stimulates further thinking about the problem solution that will consequently lead to the next, so-called evaluation phase.

Since this is the first phase of the purchasing cycle and the number of potential customers is the highest, market research is of utmost importance here. Good news is that observing customer behavior online is both efficient and easy to measure. Firms can collect the information and statistics about their advertising efficiency and get a more clear understanding about the size of their potential or current market segment. The fact that it is possible to check the advertising campaign's effectiveness in real time or find out which types of ads lead to actual purchase, enables fine tuning and improving the overall results of marketing efforts.

4.2. In-Between Phases

Since purchasing cycle may take a significan amount of time, it is not rare that custumers are also experiencing so-called in-between phases. Email marketing and GA remarketing are the tools that help customers successfully move in and out of different phases of the purchasing process. Email is one of the most important channels for communication and promotion because it takes maximum attention of the person reading it. It is suitable for maintaining the relationships with the existing customers or users, while remarketing shows ads to those people who have visited the website once or several times. Thanks to these tools, firms are able to keep in touch with both their existing and potential customers.

Besides relationship building, email is also a great tool for informing the public about the new products or special discounts etc. but the major advantage of email usage is its measurability as a communication channel. Email is cheaper and faster than the other forms of direct communication and can be set up as automatic by using email services providers such as MailChimp. Its efficiency is measured through Open Rate and Click Rate.

Open Rate is the percentage of users that have opened an email, and is calculated by using the following formula:

$$Open\ rate = \frac{Opened\ mails}{Recipients - Bounced\ mails} \times 100$$

Click Rate is the percentage of users that have clicked the link in an email, and is calculated by using the following formula:

$$Click\ rate = \frac{Clicked\ mails}{Recipients - Bounced\ mails} \times 100$$

4.3. Evaluation phase

In the evaluation phase, customers are profiled as being aware of their problem or unsatisfied need and are actively looking for the solution. In this phase, the firms should maximize the benefits of using the promotional channels such as Facebook and SEO. Since Facebook is currently the most popular social network in Croatia and worldwide, the surveyed small enterprises in Croatia have confirmed that they are most widely using this channel for their social media marketing efforts.

Facebook can help customers' navigation through awareness and evaluation phase, but it is more appropriate for the second phase because the targeting is much more precise than GA Display. The reason is that Facebook as a social network contains a lot more information about the customers and by thus carries a vast variety of possibilities as a promotional and communication channel. One of the biggest advantages to advertising on Facebook is the ability to target specific groups based on their age, gender, location, education, marital status and, most importantly, accoding to their likes on Facebook. Therefore, the benefits of marketing aspects of social media service is that it enables detailed analysis of potential customers and competitors and helps detecting the target market by which the greatest ROI is delivered over time. This is especially attractive for limited marketing budgets in the small business sector. Another major advantage of marketing on Facebook is that it is only paid when someone clicks on the ad so that for the minimum cost there is maximum accessibility and visibility. Finally, there is also so-called social listening or monitoring social media which enables firms to see how social media users and competitors see and perceive a certain product or a brand.

Search engine optimization (SEO) is a process which improves the position of a website in the unpaid section of search engines enabling companies to more effectively reach their target market. Any website search optimization process begins with precise definition of the goals, target groups and keywords according to which an optimization is then set up. This is followed by various activities which ensure that the website form, content and program solutions are adjusted to the Search Engine in order to deliver immediate, relevant, and important information to their users. Since SEO is a continual process of link building, keyword management, research and updating, this process requires time and close attention of both sides of SEO optimization (the SEO provider and the SEO user or the company itself).

Being the only form of advertising where companies are able to aim their effort directly to the people that are searching for their products and services, SEO has proven to be very effective. However, in order to receive the highest rankings, it is important to follow current marketing trends and incorporate frequent changes into the website. Many companies, especially small businesses have to increase their level of awarenss that website has to have relevant content and keywords that will be coming up on the searches, otherwise a website gains no exposure.

Website ranking is determined through extensive series of algorithms based on multitude of factors that are influencing the position of the website. Many of these factors can be altered in order to improve the website's ranking. Besides content and keywords relevance which are the most important factors that influence the website ranking, Google has also added a new social aspect that includes quantifiable information such as number of likes, shares and comments that also determine the website ranking. For this reason, it is important to share the content and interesting info with as many people as possible because that increases the number of website visits.

The part that influences the evaluation phase the most is the special quiz or a survey on a landing page of a particular website because it helps firms get the information about customers, while customers in return get the personalized answer and the specific information that helps them solve their problem or fulfill the unsatisfied

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need. According to those questions and answers, customers are divided into segments. Emails sent to the selected segments are targeted according to their specific profile and belonging style of communication. This is a valuable phase for the firm because of its potential to approach and get closer to the target market.

Blog is another excellent online marketing tool and a great source of educational and informative content which makes it a great start for any content strategy. Besides building the brand visibility, blogs also have the potential to build trust and familiarity. According to behavioral economics, so-called familiarity principle is a mental bias by which consumers make purchasing decisions based on what they are familiar with. Since blog content is easily shared through social networks, the exposure to the same thing repeatedly grows a sense of familiarity. For this reason, it is important to attract people to engage in a dialogue, share their opionions, ideas and by thus create a positive community. When a positive community is created and maintained, the level of trust is by thus increasing.

4.4. Purchase phase

Purchase phase is the last phase of the purchasing cycle. The characteristic of this phase is the smallest number of customers who precisely know what they are looking for and are interested in finding the company that can provide it. In this phase it is not important to further inform the customers because they are already prepared to make a purchase. However, it is crucial to attract the customers to the selling landing page of the firm's website. It is also essential that GA Search is included this phase because people are looking for very specific products or services functions best here.

GA Search also enables showing the ads on Google with regards to the keywords written by the potential customers. In order to channel the online traffic in the way that effectively unites the ads, key words and the website destinations which potential customers visit after clicking on the ad, the content relevance has a leading role in attracting customers' attention. There are many methods that webmasters use in order to entice potential customers to their site. The tendency is to offer pleasureable experience to customers which Google then rewards by a better evaluation of the link quality which in return means a better position of an ad with a lower price per click.

5. Conclusion

With the prevalence of the internet in today's society, traditional business strategies have been revolutionized and marketing activites evolved into more efficient ways of advertising and promotion. Nowadays companies are able to tap into a vast online market that was once out of reach. This is especially attractive for small business sector and their limited marketing budgets. Besides the great speed of sharing the content, decreased costs and a wide spectrum of users that can be reached, online marketing enables monitoring the campaign effects and results in real-time.The expenditures of online marketing are small compared to possibilities of a well developed online marketing strategy which enables ROI and ensures ravenues. The most important factors that lead to a successful marketing campaign geared towards promotion and sales growth are the content and keywords relevance as well as recognizing the position of a potential customer in the purchasing cycle. By matching the appropriate online channels of communication with particular points of the purchasing cycle, the firms may formulate unique strategies that identify opportunities for interaction with customers and maximize the advantages of online marketing such as social listening, competitive analysis or applying new analytics tools. Therefore, the goal of marketing efforts today, especially in small firms, is to recognize marketing potential of the new technologies and understand the dynamic character of the Internet as a technology, market and a social phenomenon.

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E-Commerce Sales Promotion and Group Buying Concepts

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Abstract

Sales promotion is a key element of the promotion mix. It is consisted of many short-term ways to stimulate quicker or greater purchase of particular products or services by consumers or trade. Because of the market development, globalization, computerization and some negative aspects such as recession and lower purchase power, companies are turning to online forms of sales promotion. Group buying is one of the online forms. Over the past years, group buying has become a worldwide phenomenon and there are over fifty Internet sites which provide group buying services on the Croatian market. This paper discusses the benefits and the disadvantages of group buying concept both for sellers and for consumers. The sellers conducted the primary research on the satisfaction of group buying concept.

Keywords: *sales promotion, e-commerce, group buying*

1. Introduction

The paper analyses the development of e-commerce, which is ever more important and profitable component of the overall trade in the digital age, and that requires a new approach and new marketing strategies. Shopping on the Internet has enabled the creation of virtual stores and a new digital market, which has no limits. The paper is contextualizing the digital business that allows the development of new forms of communication with consumers. One of them is the emergence of Internet portals for group buying. The study is based on the attitudes of company sales departments of businesses and industries that use sales promotion via Internet portals for group purchases. The survey included fifty-seven Croatian companies (N = 57) within different sectors, in order to determine the perceived advantages and disadvantages of this model and possible projections for future use with a special focus on customer satisfaction.

2. E-Commerce in the Context Of Marketing And Promotion

Sales promotion is an important element of the promotional mix and an important part of promotional campaigns. It consists of a variety of marketing techniques and its purpose is to temporarily add value to a product or service in order to achieve certain sales or marketing objectives [1]. It is one of the most effective marketing tools that companies use to avoid potential swift and strong reaction of consumers. The specificity of sales promotion is that it combines strategies to open up sales channels. Also, sales promotion is a continuation of the communication process with customers and the customers to the ultimate goal - the purchase of goods and services [2] and [3].

E-commerce is important because customers are encouraged to electronically search and compare products, to get informed about their characteristics, to perform purchase itself, pay and get delivery of products anywhere in the world. This performance of processes and transactions leads to a significant acceleration of business, drastic cost reduction and improved efficiency. In that sense, E-commerce can be viewed from these four perspectives [4]

- Communications perspective;
- Business process perspective;
- Perspective of service delivery;
- Virtual perspective;

Each of them contributes to the fulfilment of specific marketing strategies in an online environment. Businesses have adapted to the digital era because that enabled them to achieve differentiation, but also, with changing behaviour of consumer environment, online trading is becoming one of the main source of revenue for many companies. According to information available on the leading website for online statistics, Statistical Inc. [5], the total value of e-commerce in the B2C segment on a global level in 2013 was $ 1.2 billion while the highest selling products were apparel (24% of total sales share) and consumer electronics (26% of total sales share). When it comes to Croatian market, 2.75 million Croats use the internet, of which more than half, 53% access the Internet every day. As e-commerce is concerned, the data show that the goods and services purchased by 26% of users, an increase of 10% compared to the year 2012. However, this is still significantly lower than the EU average, which is 47% [6]. It is also necessary to briefly present some main advantages and disadvantages of E-commerce for both buyers and sellers. This is presented in the following tables.

Table 1: Advantages of E-commerce for buyers and sellers

Advantages for buyers	Advantages for sellers
Bigger choice of products/services	Data collection on consumers
Lower prices and comparability	Efficient inventory management
Product/service non-stop availability	Cost reduction
Easier access to information	Increase of speed and overall management efficiency
Time saving	Less paper documentation

Table 2: Disadvantages of E-commerce for buyers and sellers

Disadvantages for buyers	Disadvantages for sellers
Language skills and poor computer skills for certain target segments	Constant investments in technology development and UX
Risk of fraud	Competition
Potential delivery problems or time of delivery	Difficulites in trade due to product type (perishable goods)
Unability to return or change items	Lack of better business regulation

3. Group Buying as Part of Sales Promotion

Group buying is one of the latest world business concepts. The three most important factors that influenced the occurrence of this form of business and its acceptance among the vast audience (both business and consumers) are the Internet, social networks and recession. Online portals that provide a service of group buying are behaving as intermediaries between suppliers and customers. Online service, in cooperation with the bidders agrees to the products and services that will be offered as well as on the discount amount if minimum number of required buyers is met. If there is a sufficient number of customers interested in the offer and if purchase has occurred, all customer generate big discount as promised by the company offering product or service. If interest is not sufficient, offer fails, but traders have no cost because online services are not charged through displaying offers on their websites. Also, customers who have bought the offering, which was cancelled in the meantime, will not be charged.

Businesses/sellers usually give discounts of 50% to 90%, and the minimum number of interested customers is through the threshold of profitability. Also, sellers can determine the maximum number of customers that can apply for a specific offer or purchase coupons. Offers have a certain lifespan, and this is usually a week. If the offer ends up as valid buyers get their coupons for a discount through e-mail. Every day in Croatia there are over 300 new group offerings published on various portals that provide intermediation services. One of the first and the most successful global portal for online shopping is Groupon, which justifies the name of the market leader not only in the number of users but also the number of cities covered by their tenders - 70 North American cities and 140 cities around the world [7]. In Croatia, the group buying emerged relatively recently, respectively in 2010. With the launch of the portal Kolektiva.hr, and until today Croatia has more than 50 groups buying portals.

4. Research Methodology

Given that the concept of group buying benefits to customers, we were trying to focus more on the sellers. The questionnaire was distributed to 205 e-mail addresses of companies that advertise their offers on the sites of

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group buying. In a final sample of fifty-eight (N = 58) of surveyed companies who answered the questions and were engaged in various activities, research will show how are the sellers satisfied with the performance of the business model of group buying regarding their operations, what do they consider to be the main advantages and disadvantages of the model, how satisfied they are with intermediaries (portals and sites) and would they use the same promotional tool in the future again.
The questionnaire is structured in three groups of questions / statements described using Likert scale (1-5) to determine the degree of agreement with issues / claims that were questioned. The collected data was statistically processed, and the comparative method, the method of deduction and synthesis was adopted to draw relevant conclusions.
Questionnaires were distributed by e-mail addresses that were previously collected on portals/sites for group buying; *Kolektiva, Crno Jaje, Megapopust, Kupime and Ponuda Dana*.

5. Results of Research on Sellers Satisfaction of Group Buying

The first question was related to the activity and business sellers are engaged in. The range of activities is shown in the figure below.

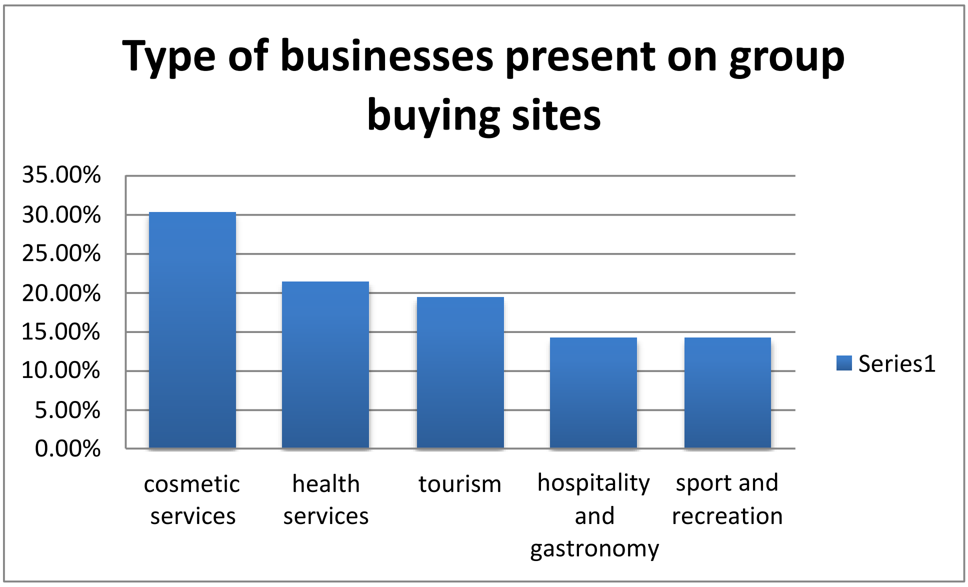

Figure 1. Type of businesses present on group buying sites

Given the previous years, we can conclude that the group buying portals significantly reduced catering and hospitality offers. Due to the fact that their cost of food is the same as if they were serving regular clients, their profitability is the most dubious. Also, currently the group buying portals are offering more and more products while they used to be more focused on services. Products that are offered are jewelry, food, clothing, various electronic products and the production and delivery of sweets.

The next question included the intensity of the business model, i.e. how many times has a company announced an offer to group buying portals.

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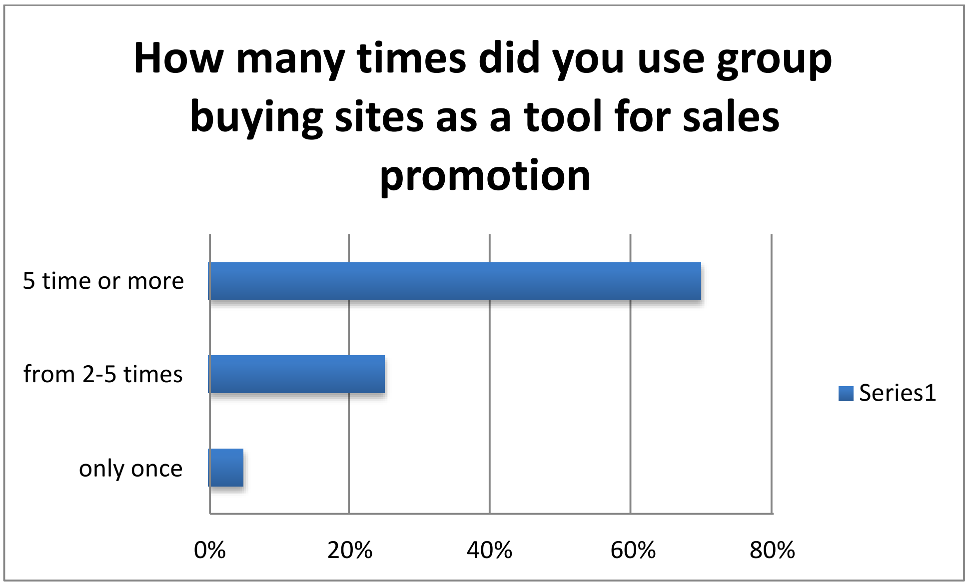

Figure 2: Usage of group buying sites

Of all respondents, 70% of the respondents used the model of group buying in their business for more than 5 times. The remaining 25% used the model of group buying up to 5 times while only 5% of the respondents used the model for the first time. Also, it is important to emphasize that the majority of respondents advertised in at least three portals at the same time.

The following graphical representation shows that intermediaries for group purchase excel in the selection of respondents. In this survey question it was possible to select multiple responses, which respondents did.

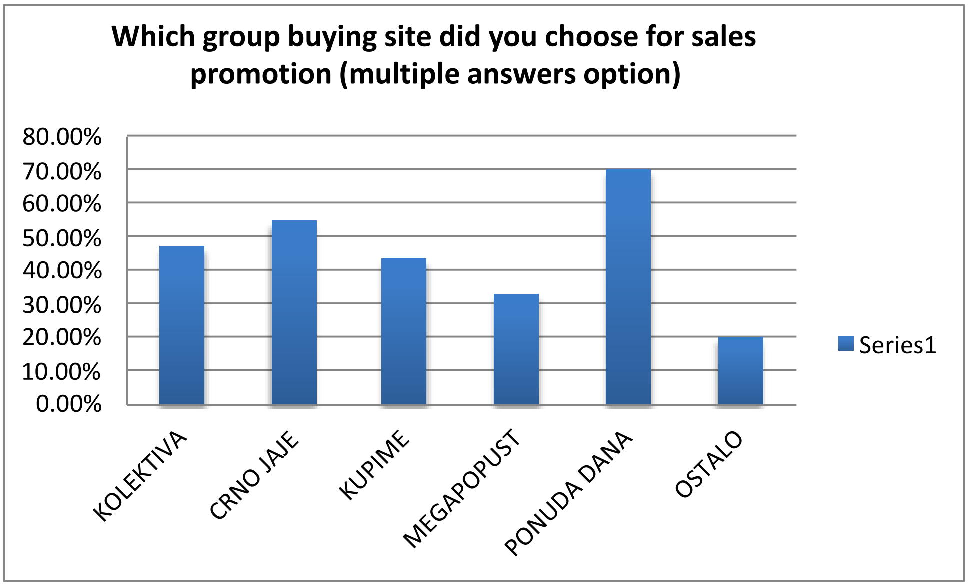

Figure 3. Particular group buying sites used by the sellers

According to the test sample, most companies opted for the portal Ponuda dana. Crno Jaje follows with roughly 55% and Kolektiva with 47.17% Kupime is third most popular with 43.4%. Given the fact that the questionnaire gave the option "Other" with the possibility of specifying other Internet portals for group buying, respondents have opted for one of the following portals: *Grupnjak, Popust Plus, Kupi u grupi, Megabon, Povoljno.hr, Kupi zdravo, Promotiva* te *TiDamTiDam.*

The next question shows what are the motives of using this type of sales promotion. Respondents could choose from couple of answers and evaluate them on a scale of 1-5. The possible responses were: promotion, attracting new customers, create loyalty and profits.

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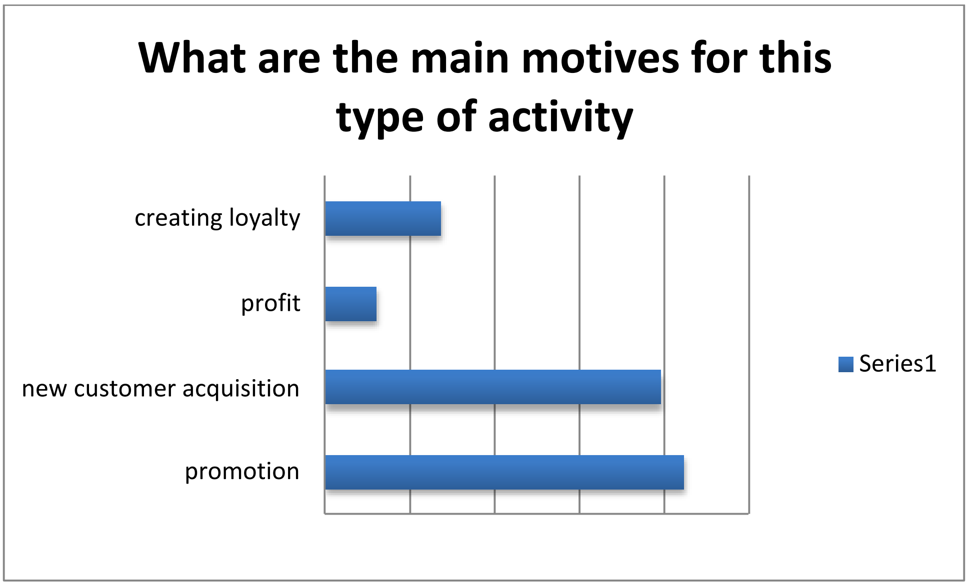

Figure 4. Main motives for using group buying sites

Given that the majority sellers are SME’s, most of the respondents pointed out the promotion and new customer acquisition as the main motive for the usage. Even 84.62% rated promotion as most important while 79.25% thought that for new customer acquisition. When profit is concerned, only 12% of respondents highlighted the profits while creating customer loyalty was valued with share of 27.08%.
On the other hand the research has shown as seen on Figure 5 that the largest number of respondents believe that lack of profitability and customer disloyalty are the greatest weaknesses of the business model. Healthcare providers are the most concerned of the negative side-effects regarding their reputation.

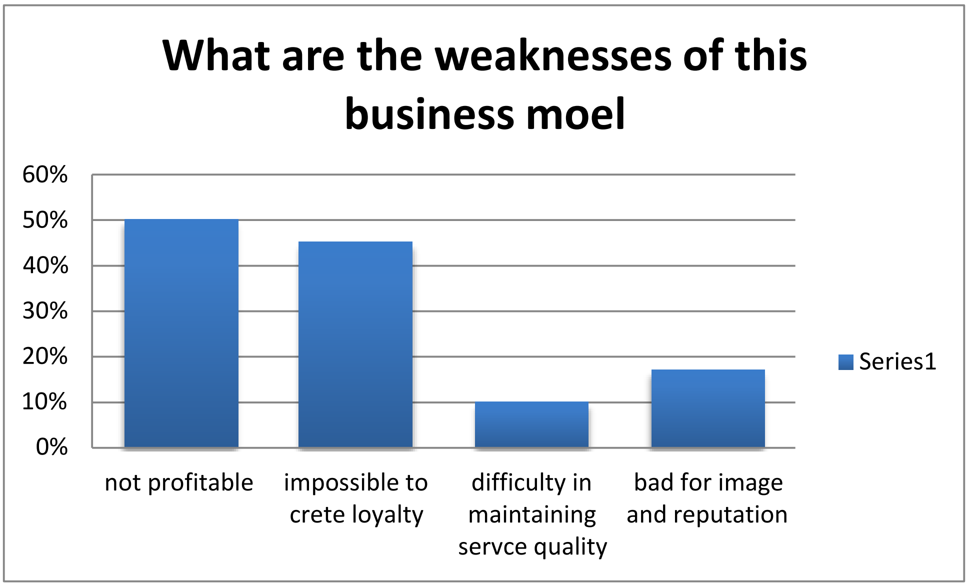

Figure 5. Main weaknesses of group buying

In many of the comments written in open-answers part, sellers have doubts in customer loyalty because they perceive that customers buying on sites for group buying are mainly "opportunity hunters". Companies that have embarked on this venture for profit or creating loyalty in most cases are not satisfied with the model.
Last question examines the likelihood of repeating of group buying as a sales promotion model. It is interesting that more than 80% of the companies would like to repeat it, regardless of their dissatisfaction with certain parts of the model.

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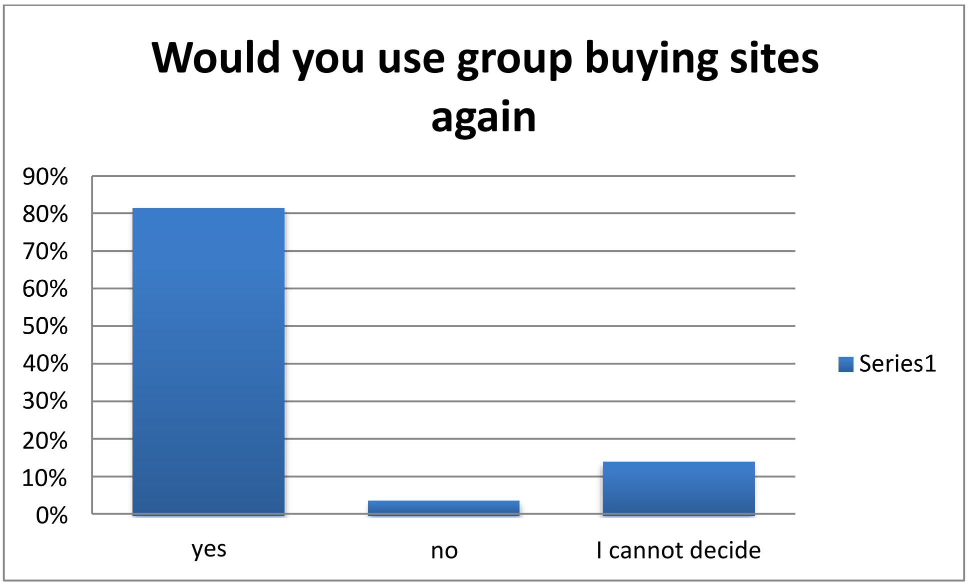

Figure 6. Readiness to use group buying sites again

6. Conclusion

New technologies make an important variable of overall economic growth. Investments in online technology and new business models enables the presence of companies in the Internet economy thus creating opportunities for growth and business development outside the boundaries of the physical market. E-commerce is considered to be one of the most profitable form of trade due to the low cost and efficiency. It is much more effective compared to the traditional form of trade because it provides a larger market, availability of products, time saving and flexibility in business.

The growth of e-commerce in Croatia is the result of growing awareness of entrepreneurs about all the advantages of online commerce and general business operations on virtual markets.

Given that the benefits of group buying for customers are more than clear, the aim of this study was to examine the concept of group purchasing from the perspective of sellers. Traders need to seriously develop the model, and examine options and cost-effectiveness model. It is necessary to have efficient staff and employees and try to differentiate. Primarily, it is a good knowledge of fixed operating costs, particularly unit costs in order to examine the feasibility of the model while ensuring the quality of service on an optimal level.

7. Authors

Nela Maras, MBA, holds a bachelor and a Master Degree from the Zagreb School of Economics and Management. During her studies, Nela Maras participated in many student activities and was one of the best and most ambitious students. During her studies, Nela gained valuable international experience as a participant of International exchange on prestigious Koc University in Istanbul Turkey.

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Ana Kuštrak Korper, MA, MBA, graduated systematic musicology at the Music Academy University of Zagreb in 2011 and business administration in the field of marketing in 2012 at the Zagreb School of Economics and Management. She was awarded a special Rector Awards in 2008 and Rector's Award 2009 and she was a visiting scholar at the Ross School of Business, University of Michigan, in the United States. She is currently working as a lecturer in Marketing and Communications Department at ZSEM.

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Evolution of technology in risk management

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Abstract

This paper presents the field based evidence on changes in risk management practices in Swiss banks after the subprime crisis. Prior to the crisis risk management was dominated by technology, i.e. use of IT tools and complex models. In the most general terms the study concludes that the Swiss banks are slowly moving towards the culture of quantitative skepticism. The study concludes that installing and maintaining risk culture based on natural skepticism is the most crucial part, as well as the biggest remaining challenge and opportunity to improvement of risk management. Usage of IT and proprietary models lost their focal point and became just a starting point of the holistic based risk analysis.

As this study argues for a more systematic view of risk it is also an extension of that stream, which additionally argues for a more holistic, independent and systematic risk management. It is a direct extension of the works of Mikes (2009) and Power (2009), as the study provides evidence that the culture of empirical skepticism is dominant in Swiss banks. Further, it extends on related concepts of two risk methods and four risk types by providing empirical evidence from Switzerland.

Keywords: *risk management, technology, subprime crisis, organizational change, calculative cultures, banking.*

1. Introduction

In this paper presented are results of a field study or applied research [1] that aims to contribute both academically and practically to the better understanding of the ERM (enterprise risk management) process in Swiss banks. Research is designed to be an explanatory since it is grounded in theory, but attempts to go beyond description and attempts to explain the phenomenon. Only a portion of much larger study is presented in this paper.

The empirical part of the overall study aims to show how risk management in Swiss banks is changing as a result of the subprime crisis. This paper is focusing on how utilization of technology changed, as a result of that.

2. Theoretical background

The relatively recent literature recognizes the conception of two alternative risk models: “one driven by strong shareholders value (RM by the numbers and influenced by auditing and compliance), and other corresponding to the risk-based internal control imperative (holistic ERM and independent).” [2] Prior to crisis RM by the numbers was a more popular approach, and overwhelming support for this model is rooted in numerous accounting/audit centric regulations,[3] i.e. SOX in the US, Law on Financial Security (LAS) in France, etc. Technology is heavily utilizes in this approach, and dependence on proprietary models, software solutions and technology was significant. Proponents of the stream argue that their approach”…builds on established audit methodologies by combining governance and risk management principles.”[4] Although this perspective might be acceptable for other industries it should have not be applied to banking, for several reasons. Many companies are swamped with responsibilities introduced by the Sarbanes-Oxley (SOX) and other legislations; therefore, they adopt check-the-box mentality and apply SOX section 404 as a one-time project,[5] instead of as an ongoing practice. “For example, in Europe, and particularly in France, internal control failures severely impacted Airbus Industrie in 2006 and Societe Generale”[5] particularly because internal controls and overall risk management were treated as a one-time projects. Even worst, in many cases auditors are implementing only internal controls without risk management, but we know that effective ICS without risk management is not possible.[6] Further, the effectiveness of audit based risk management is elusive, as auditors are historically

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willing to give an opinion on management processes, but remain hesitant about reporting on internal controls and risk management due to liability concerns.[7] Finally, there is an obvious conflict of interest if an auditing department is responsible for designing, implementation, and control of all reporting and most of the company. On the other hand, the benefits of the independent risk management (holistic ERM) function headed by CRO are numerous, including reduced information asymmetry between current and expected risk profile,[8] reduced volatility, added value through better decision making and higher profitability, reduction of downside risk,[9] reducing the expected cost of external capital, reducing regulatory scrutiny,[8] and so forth. To this end this paper contends towards the independent risk management function, and argues that independence is a key component of effective ERM and effective ICS in banks. This logic is an extension of a limited research stream argues for the independent risk management, and for the more significant and systematic management of strategic risks in order to avoid the possibility of more serious value destruction in the future.[10] This research stream appeals to shift from “ERM by numbers” to “holistic ERM”, and urges for less reliance on models and technology, and more uses of softer instruments. Until now, this research stream was primarily focused on exploring and describing phenomena, as well as presenting theoretical concepts; hence, several practical aspects are missing. It is worth noting that, the majority of this research stream did not include Swiss banks.

This researcher feels this is a substantial unexplored research area. It is worth noting that this stream does not necessarily call for more complex or bigger ERM, but rather more “intelligent”[7] ERM, with increased organizational significance.[2] This logic is also extension of the New Corporate Governance (NCG) approach that recommends a separate risk management function headed by CRO.[11] Finally, considering that the literature stream with strategic focus lacks insight into the integration of corporate governance, risk management, and alignment with internal controls, this study contends that is the next logical step in the evolution of ERM. The failures of internal controls seem to be well documented.

Not to be misunderstood, the utilization of proprietary models and technological solutions is an integral part of holistic approach; however, outputs of implemented technological solutions become a starting point for the discussion of risks. Prior to crisis model outputs were never seriously examined, but just accepted for granted.

3. Research methods and limitations

This study utilizes pragmatism as a philosophical position, which implies the use of mixed or multiple method designs for data collection.[12] Following that logic this study employs the nested mixed method design, in which the quantitative part has a lower priority, and is embedded in the qualitative part.[13] Use of multiple methods is increasingly advocated within the business and management research, as it allows for use of qualitative and quantitative techniques and procedures as well as use of primary and secondary data.[12]

The use of multiple methods allow for a better opportunity to answer the research question as it allows for better evaluation to which the research finding can be trusted and inferences made from them. It is well suited for sensitive topics (like ERM) as it allows easier access to relevant information and provides multiple perspectives on the topic.[14] One of the big advantages a multiple method approach is that different methods can be used for different proposes. In this study, the questioner is used to make inferences about the overall population that includes all Swiss banks. Semi-structured interviews are used to gain valuable, in-depth insight on the phenomenon.[15] The chosen methods complement each other well, as quantitative part will be used to confirm the valuable insight gained in the qualitative study.

Semi-structured interviews were conducted with senior executives including ones form the largest banks, leading academics, regulators, in late 2012 and early 2013. A total of twelve interviews were conducted, please see figure 1 for breakdown by type of interviewees.

Respondent	Number
CRO's	4
Senior risk officer	2
Chairman of the BoD	1
Regualtors	3
Academics	2
Total	12

Figure 1. Breakdown of the interviewees

A total of 100 banks were chosen through the systematic sampling, however, the researcher was unable to obtain a valid email address of the head of risk management in 6 banks (n=94). A researcher received a total of 35 responses. Ten questionnaires were not included in analysis due to missing filed. Six participants sent an email explaining they are unable to complete the survey, as no one in their organization has the expertise/knowledge to answer all the questions. These six responses were not dismissed from the analysis, as several conclusion can be drown from their "non-response". Subsequently, the researcher received a total of 25 significant responses that will be used in analysis (please see figure 2).

	Number	Percent
Questionnaires sent	94	100%
Total Responses	35	37%
Missing fields	10	11%
Unable to answer the survey	6	6%
Valid questionnaires	19	20%
Significant	25	27%

Figure 2. Response rate

The biggest limitation of this study is inclusion of all banks, regardless of ownership, size, etc. Even though all banks are governed by same regulations, differences are quiet significant. The primary concern for this study is generalisability or external validity, as the research will produce recommendations that are generalisable to the population of all banks. Several measures were employed to mitigate this issue, which included use of representative sample and use of various research methods, i.e. triangulation.

4. Results

The empirical findings once again confirm the theoretical findings that banks have various risk management practices and that their unique risk management mix can be classified in one of the four ideal types of risk management (in order of complexity they are silo, integrated, risk-based, holistic).[16] The silo-risk management approach is evident in the smallest banks, and as mentioned risk management in those banks is being modified only in response to regulatory pressure. Such institutions usually have a simple business model, a sound capital structure and sufficient liquidity, in other words they are very financially stable, and that is why they do not raise many regulatory concerns. Yet, although this recent pressure from FINMA (the Swiss Financial Market Supervisory Authority) is still quiet low, but it is obviously aimed at the implementation of a more integrated approach, i.e. the integrated risk management. Implemented technological solutions capturing quantifiable risks suffice for present time, but complete reliance on such solutions is extremely rare. In the next couple of years the silo-risk management approach might disappear from Swiss banks due to the mentioned regulatory pressure. Further, empirical evidence not only confirms the existence of all four risk management types, but also indicates a possible evolution of the mentioned categories. The most obvious indication is the use of soft tools (scenario analysis, sensitivity analysis, etc.); as empirical evidence confirms almost all banks utilize those tools – traditionally a characteristic of the holistic type. Further, all banks are also considering all risks (including non-quantifiable risks), and adopting a more systematic and strategic view of risk. It is inconclusive from the empirical evidence which type of risk management is the most represented and whether categories should be modified, but it is clear that based on cost-benefit analysis banks are adopting more complex types of risk management. All banks have significant investment in IT infrastructure, due to utilization of the more complex ERM approaches and regulatory requirements. More data is being compiled and closely analyzed; however, outputs of models are used only as a starting point in the risk analysis. Finally, only the largest institutions have fully implemented ERM that includes corporate governance and internal controls dimensions, and as this is a significant paradigm shift it might warrant a new category.

Empirical evidence indicates that culture should be a focal point of the risk management modifications, a risk culture based on natural skepticism and integrity. That is somewhat surprising since 60 percent of participants suggest that their organizations are effective at installing and maintaining a risk aware culture; and even more surprising since only about quarter of respondent agrees that risk training is effective at all levels. Empirical findings coincide with the theory that tone is set at the top by the board, championed by the senior management and the CRO at operational level [17] and that it is crucial to involve all employees. The tone that is set at the top is crucial as it channels down to the entire organization through strategies, objectives, etc. Calculative cultures can be divided in two categories, so if the board and senior management place emphasis on robust risk

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models and technology they tend to foster the culture of quantitative enthusiasm; however, if models and technological solutions are used as indicators and focus on underlying risk profiles then quantitative skepticism is fostered.[2] Empirical evidence suggests that the Swiss banks are striving towards the culture of quantitative skepticism. Further, empirical findings demonstrate that most banks survey all employees in regards to risk management, even though this issue is not addressed in the literature.

Empirical evidence suggests that in each organization there are two levels of change, while structural changes took place in most banks, it will take a long time for behavioural change to be fully implemented, as it is crucial to lead by example and continuously spreading the risk management message at all levels. Further agreement is that culture needs to be explicit, as explicit tasks and responsibilities make it easier to implement controlling and reporting functions leading to improved strategic leadership.

Empirical findings confirm that the "make as much money ASAP" attitude was detrimental to risk culture during the crisis.[18] Evidence from the field demonstrates that culture should be shaped through guidelines, rules, and training; yet only two participants stated their organizations have specific risk training. Once again it was reiterated that the lower management should be relieved from less important duties and focus on RM. With more time to devote to RM those managers could continuously train/educate employees.

The theory states that an excessive risk taking culture in banking is a result of incentives introduced through compensation policies, and in their opinion this excessive risk taking needs to be addressed.[18] As remuneration is inextricably linked to culture, it is important to consider risk adjusted performance measurements and rewards, but more on this in the next section.

Naturally, abrupt changes in culture can have undesired results, i.e. an increased pressure on advisors to modify their behaviour/culture might lead to them leaving and taking clients as well.

Finally, the empirical evidence indicates that installing and maintaining risk culture and natural skepticism are more crucial for the front office, as it can often be found in the back office but not the front.

5. Conclusion

Empirical results confirmed the theoretical predictions that the ERM is becoming more holistic, more independent and less dependent on models and technology, and more integrated since the crisis. The study confirms that there is a clear shift from ERM by numbers to holistic ERM. That is obvious as banks of all sizes are considering all risks (including non-quantifiable risks), and adopting a more systematic and strategic view of risks. This shift is further emphasized through the requirements of the Swiss regulator FINMA. The FINMA mandates higher utilization of technology as more data needs to be captured, but requires more holistic decision making process.

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Engineering Students' Perception of Studies – a Comparison Based on the Students' Educational Background

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Abstract

Students enter higher engineering education with many different educational backgrounds. For example, the new engineering students of the Turku University of Applied Sciences (TUAS) consist of upper secondary school graduates with different selection of studies in Mathematics and Science, as well as students with various vocational qualifications many with modest additional mathematical studies after compulsory schooling. This heterogeneity presents one of the main teaching and learning challenges especially during the first part of the engineering studies. In this paper, a small-scale survey to the students of the Degree Program in Information Technology at TUAS is presented and discussed. The main research question was to find out how do students with different educational backgrounds describe their study paths, and to analyze if there are differences between these categories: Which courses the students have considered interesting, easy or difficult? The results indicate that there are certain statistically significant dependencies between the responses and the students' educational background.

Keywords: *Curriculum, Information Technology, Mathematics*

1. Introduction

Topics dealing with delayed graduation and discontinuation of studies in higher education have frequently been in the headlines during the past few years (see e.g. [1]). Similar reasons seem to lead to student drop outs in the different branches of higher education all over the world. According to Liimatainen et al. [2], the most important reasons behind delayed graduation both in academic universities and universities of applied sciences in Finland deal with working during the studies, lack of study motivation, psychological problems, and family-related issues. On the other hand, also variables like the student's age at the beginning of the studies, parents' educational background, and academic performance and success during the studies often appear to correlate with student drop outs [3]. Thoughts hindering the reaching of educational and career-related goals have also been shown to correlate with the drop out risk [4]. Although similar problems are present in all fields of education, engineering is one of the main areas of concern dealing with student attrition. Shuman et al. [5] reported that approximately only a half of the students entering engineering education ever graduate, and roughly a half of drop outs take place during the first academic year. These types of figures are the reality in many Finnish engineering degree programs as well.

Students enter higher engineering education with many different educational backgrounds. For example, the new students of the Degree Program in Information Technology at Turku University of Applied Sciences (TUAS) consist of upper secondary school graduates with different selection of studies in Mathematics and Science, as well as students with various vocational qualifications many with modest additional mathematical studies after compulsory schooling. This heterogeneity presents one of the main teaching and learning challenges especially during the first part of the engineering studies.

The goal is to provide such a learning environment that the admitted students have equal possibilities to learn and, finally, reach the same core learning objectives regardless of their educational background. However, there are rather limited possibilities to tailor the teaching and learning processes so that they fit the different needs of individual students or even the different student categories. That is, understanding the characteristics of the first-year students, is important, for example, in order to prevent drop outs.

The topic has been studied from different perspectives at the ICT engineering education of TUAS during the past few years. In 2011, the challenge was approached by quantitative analyzing of a set of student cohorts [6]. These results advised that roughly 55% of the students did not finalize their studies. In addition, the first academic year seemed to be critical concerning the risk of dropping out in this degree program, too. More than 70% of the drop outs in the studied cohorts had completed less than one year's studies. Yet, no significant evidence supporting the hypothesis that the students' educational background, especially in terms of Mathematics, correlates with the risk to drop out was found.

Furthermore, it has been reported how do the lecturers describe the differences between the students with different educational backgrounds, how they consider these differences in their teaching, and how could the learning of different students be better supported [7]. Most of the lecturers had experienced significant differences between the students, partly based on their educational background. Many lecturers consider these differences by, for example, providing alternative ways to complete the courses. In addition, some colleagues experience working with the heterogeneous student base very challenging or even frustrating. Topics in motivation and general study skills were seen as the main areas for improvement.

In this paper, the series of the previously published studies [6] and [7] is continued. The results of a small-scale survey to the students of the Degree Program in Information Technology at TUAS are presented and discussed. The main research question was to find out how do students with different educational backgrounds describe their study paths, and to analyze if there are differences between students with different educational backgrounds. Which courses the students consider interesting, easy or difficult?

2. Research Question and Methods

The aim of this study was to complement the mixed-methods approach of the studies presented in [6] and [7] by providing yet another important perspective to the topic. That is, it is interesting to gain information also on the students' thoughts and experiences on their studies. The research questions of this study were: How do students with different educational backgrounds describe their study paths? Are there differences between students with different educational backgrounds? The focus was set to study which courses or disciplines are considered interesting, easy or difficult by the students.

The study was implemented as a survey questionnaire that was distributed to the students currently studying in the program. The students answered the questionnaire anonymously in order to ensure that they were willing to answer openly without being forced to reveal their thoughts to their fellow students or faculty members. The privacy of the individual students was thus ensured.

Answering the survey was not compulsory. However, the implementation of the questionnaire was carefully planned in order to ensure a proper response rate. There were ca. 330 students present in the program when the survey was distributed, and the original goal was to achieve a response rate of at least 30%. The plan was to analyze the responses using mainly quantitative approach. The answers were first categorized and then studied using statistical tools.

3. Results

Earlier experiences with surveys directed to the students of the degree program had shown that it is very difficult to achieve a significant response rate with web-based approaches. Thus, it was decided to implement the questionnaire using a traditional paper form. The answers were collected by visiting each of the 12 study groups (3 groups per academic year) of the program during a tutoring session or a course common to all students of the group. The first group was visited on September 14th 2011 and the last on November 14th 2011. In the beginning of each session, the goals and contents of the survey were first presented, possible questions were jointly discussed, and then the students were asked to answer the questionnaire using the given form.

The students were asked which courses they had considered interesting, easy or difficult. In addition, a set of background variables were asked to identify the profiles of the respondents (their educational background, for example). The questionnaire was implemented in Finnish (native language of most of the respondents).

The questionnaire was answered by 189 students. That is, the response rate concerning the total population (323 students as of September 20th, 2011) was as high as 58.5%. That is, almost two times more students answered the questionnaire than it was originally expected. However, an obvious limitation caused by the method of data collection was that only the students present in the group tutoring sessions answered the questionnaire. It is possible that some of those with high risk of dropping out did not participate in the sessions in the first place and, thus, were excluded from the survey.

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The profile of the respondents is presented in Table 1. The data includes the number of students with different educational backgrounds, their gender, as well as their current phase of the engineering studies (number of completed credits when answering the survey). It shall be noted that the results are based on the students' answers only, i.e. there are uncertainties present in the number of credits especially. Some respondents did not answer their number of credits at all (those empty answers are not included in the average and deviation calculations). Furthermore, 17 students indicated that they have a double degree, i.e. both a vocational qualification and an upper secondary school certificate. These students are counted in the vocational background category since most of them typically apply to the degree program via the vocational path and are placed into the vocational course group in the beginning of their engineering studies.

Table 1. Profile of the respondents (total 189 answers) of the Student Survey.

1st Academic year	#	Number of credits		Gender	
		average	st.dev.	female	male
Total	72	2,0	3,2	6	66
Vocational qualification [1]	25	1,3	1,5	4	21
Upper Sec., short Math.	22	4,1	4,8	0	22
Upper Sec., long Math.	25	0,8	1,3	2	23

2nd Academic year	#	Number of credits		Gender	
		average	st.dev.	female	male
Total	47	63,1	13,6	8	39
Vocational qualification [2]	24	63,7	17,3	3	21
Upper Sec., short Math.	11	61,2	6,9	4	7
Upper Sec., long Math.	12	63,8	9,6	1	11

3rd Academic year	#	Number of credits		Gender	
		average	st.dev.	female	male
Total	36	111,0	16,5	6	30
Vocational qualification [3]	20	107,3	13,8	3	17
Upper Sec., short Math.	7	122,0	19,7	1	6
Upper Sec., long Math.	9	111,4	16,1	2	7

4th Academic year	#	Number of credits		Gender	
		average	st.dev.	female	male
Total	34	182,1	19,2	2	32
Vocational qualification [4]	14	191,3	14,0	0	14
Upper Sec., short Math.	13	174,8	22,0	2	11
Upper Sec., long Math.	7	175,2	13,9	0	7

All respondents	#	Number of credits		Gender	
		average	st.dev.	female	male
Total	189	68,4	68,2	22	167
Vocational qualification	83	77,2	67,9	10	73
Upper Sec., short Math.	53	70,6	71,2	7	46
Upper Sec., long Math.	53	51,9	62,3	5	48

[1] Three double degrees (Vocational + Upper Secondary School)
[2] Seven double degrees
[3] Three double degrees
[4] Four double degrees

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So, the students were asked which courses (past or current) they have considered interesting, easy or difficult. The answers were given using open text fields with no preprocessed alternatives in order to avoid bias. The responses were analyzed and categorized so that same courses or subjects were identified and merged. Courses mentioned in at least three responses on one academic year were listed separately, and other responses were listed in the category 'Others'. The listed courses and course groups included the following:

- Science [Mathematics and Physics]
- Languages [Swedish, English and Finnish (native)]
- Software [Software Engineering and Programming related courses]
- Hardware [Electronics, Circuit Theory]
- Data Networks [Internet Technology, Cisco Networking Academy courses]
- Introduction to Digital Media [Digital media applications]
- Computer Skills [Office applications]
- Computer Design [Boolean Algebra, Logical Circuits]
- Algorithms [Data Structures, Complexity Theory, Computing Algorithms]
- Major Subject [Courses in the specialization topic]
- PBL [Courses utilizing Problem-Based Learning]

All the other items represent a course or a set of courses except for the 'PBL'. The curriculum of the degree program contains courses that utilize Problem-Based Learning as the foundation of the learning and teaching methods applied during these courses. During the first academic year, the students have a PBL-based course running throughout the year, and also certain more advanced courses include flavors of PBL pedagogy. PBL was mentioned separately in several answers and, thus, it was included in the list even though it does not represent a course or subject in a similar way as the other items.

Table 2. Summary of the responses on which courses/subjects were found interesting, easy or difficult (N = 189) categorized based on the respondents educational background. The fields marked with * indicate statistically significant differences based on the educational background.

Interesting	#	*Science*	*Languages*	*Software*	*Hardware*	*Data networks*	*Intro to Digital Media*	*Computer Skills*	*Computer Design*	*Algorithms*	*Major Subject*	*PBL*	*Other*	Sum
Total	189	**30**	5	**45**	2	24	17	7	11	3	50	35	28	*257*
Vocational qualification	83	**21** *	1	**10** *	1	14	9	3	7	2	22	19	9	*118*
Upper Sec., short Math.	53	**8** *	2	**5** *	0	6	5	3	3	1	13	11	10	*67*
Upper Sec., long Math.	53	**1** *	2	**30** *	1	4	3	1	1	0	15	5	9	*72*
Easy														Sum
Total	189	**43**	45	26	7	7	11	21	6	1	14	11	6	*198*
Vocational qualification	83	**6** *	17	14	6	4	6	10	4	0	9	3	3	*82*
Upper Sec., short Math.	53	**12** *	15	5	0	1	2	6	2	0	4	5	1	*53*
Upper Sec., long Math.	53	**25** *	13	7	1	2	3	5	0	1	1	3	2	*63*
Difficult														Sum
Total	189	**76**	**28**	25	**27**	10	0	0	**24**	11	1	7	3	*212*
Vocational qualification	83	**45** *	**19** *	10	**5** *	2	0	0	**10** *	4	1	1	1	*98*
Upper Sec., short Math.	53	**23** *	**0** *	7	**14** *	2	0	0	**13** *	5	0	2	1	*67*
Upper Sec., long Math.	53	**8** *	**9** *	8	**8** *	6	0	0	**1** *	2	0	4	1	*47*

* = Significant dependency on educational background

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Although most of the courses are, in practice, the same concerning the respondents on the different academic years, the curriculum has been developed step by step throughout the years. That is, there are certain differences in the curriculum, course contents, and teaching and learning methods between the student cohorts. Yet, as the number of respondents per academic year was still rather low, the results presented in this paper were analyzed as a whole (including all the respondents regardless to the phase of their studies) even though there are certain curricular differences between the cohorts. The result summary is presented in Table 2 and Figure 1. Possible dependencies between the responses in each category and the students' educational background were analyzed using Pearson Chi-Square tests. That is, the tested hypothesis was whether there is a statistically significant difference in the responses based on the respondents' educational background or not.

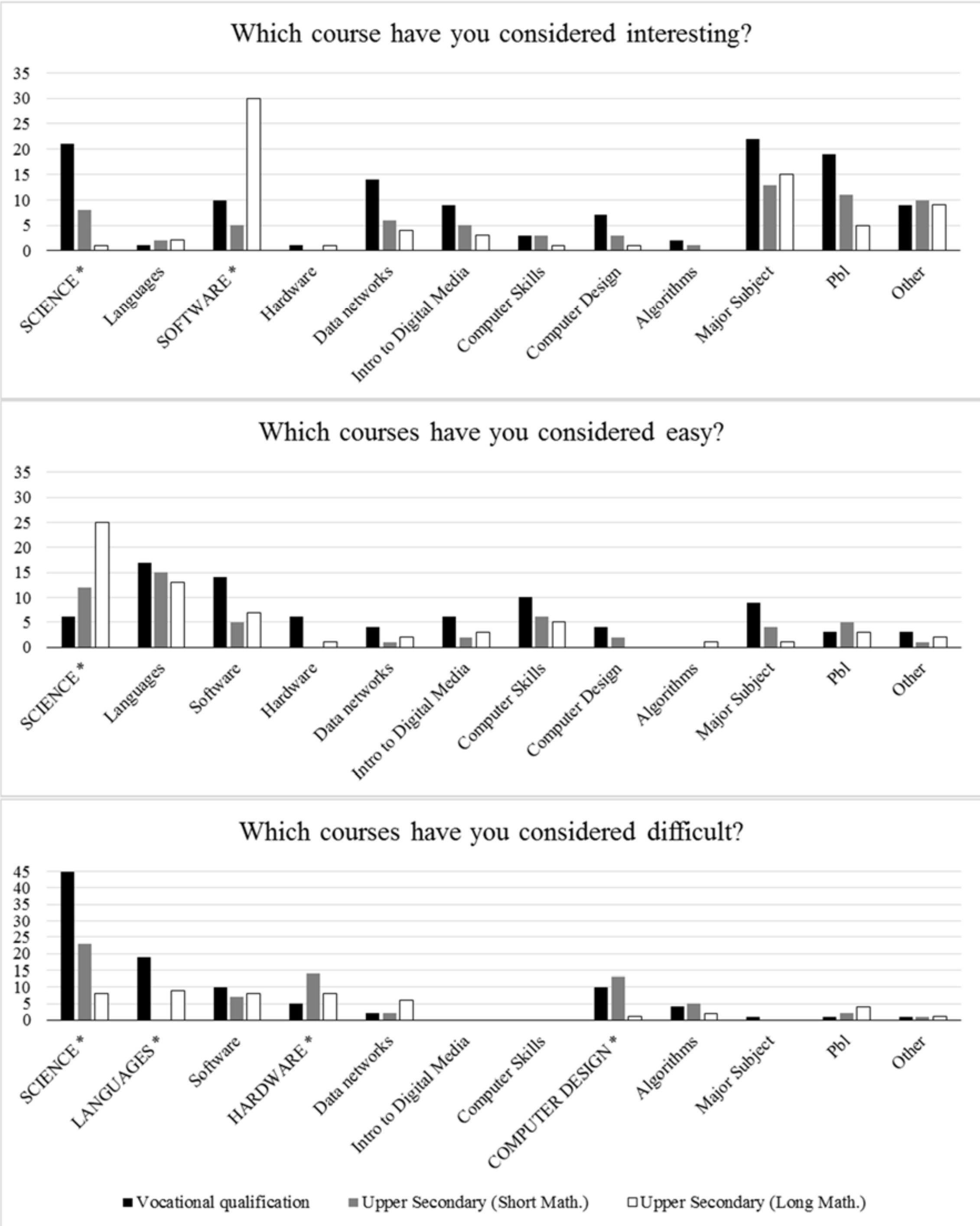

Figure 1. Summary of the responses as chart illustrations (compare with the data in Table 2). The courses marked with * (and given with capital letters) indicate statistically significant differences based on the educational background.

The five most interesting items were Major subject courses (50 responses), Software Engineering (45 responses), PBL-based course implementations (35 responses), Science courses (30 responses), and courses in Data Networks (24 responses). Respectively, the main items experienced as especially easy were Languages (45 responses), Sciences courses (43 responses), Software Engineering (26 responses), and Computer Skills (21 responses). On the other hand, Science courses were clearly considered as the most difficult ones by many respondents (76 responses), followed by Languages (28 responses), Hardware (27 responses), Software Engineering (25 responses) and Computer Design (24 responses) courses.

Experiences at both the level of interest, easiness and difficulty of the Science courses were found to be dependent on the background education ($p = 0.001$ / $p < 0.0005$ / $p < 0.0005$). Only a few students who had completed upper secondary school with "long" Mathematics considered the Science courses as difficult or interesting and, instead, especially many of the students with a vocational background experienced the courses as difficult but also interesting. Few upper secondary school graduates with "short" Mathematics considered Science especially interesting but rather many considered it as a difficult subject.

No upper secondary school graduates with short Mathematics considered the language courses difficult by, but 19 students (23%) with a vocational background and nine students (17%) with long Mathematics did so ($p = 0.001$). More than one half of the long Mathematics students (30 responses (57%)) experienced Software Engineering as especially interesting, but only a few short Mathematics students (five responses (9%)) and vocational students (10 responses (12%)) agreed ($p < 0.0005$). Significant dependencies based on the students' educational background were also found concerning the difficulty of the Hardware and Computer Design courses ($p = 0.004$ / $p = 0.002$).

4. Conclusions

The main objective of this study was to find out how students with different educational backgrounds experience their studies. Which courses or disciplines are considered interesting, easy or difficult by the students?

According to the student survey, the most interesting topics were courses in the specialization [major] subjects, Software Engineering, PBL-based course implementations and Science courses. The main topics experienced as especially easy were Languages, Sciences courses, Software Engineering, and Computer Skills. On the other hand, Science courses were clearly considered as most difficult by many respondents (40%), followed by Languages, Hardware, Software Engineering and Computer Design courses.

Experiences on the level of interest, easiness and difficulty of, especially, the Science courses were found to be dependent on the background education. Only a few upper secondary school students with "long" Mathematics considered the Science courses difficult or interesting and, instead, especially many students with a vocational background experienced the courses difficult but also interesting. The upper secondary school graduates with "short" Mathematics rarely considered Science interesting but rather many considered it a difficult subject.

The response rate of the questionnaire was very high; much higher than TUAS student surveys typically have. Because of the large number of answers, there is reason to believe that the data contains a relatively reliable source of information. However, the number of responses was still limited considering specific sub-groups. Thus, even these results shall be interpreted with a proper level of caution. Furthermore, the responses were collected during the contact teaching sessions of the different course groups, i.e. the students that were not present were excluded from the survey. This may have caused that certain students with higher risk to drop out or to get delayed in their studies were not reached. Yet, the survey still provides interesting results for further discussion.

A common question in curriculum design is how to organize the balance between the courses providing contextual perspective (e.g. project assignments requiring application of a multitude of competences) and the courses focusing to strictly disciplinary content. Furthermore, where and when to learn the basics required prior being able to dive into the "interesting" engineering applications. Especially the courses in Science are challenging to allocate. If you focus too much on these topics in the beginning of the studies, the content can get very theoretically heavy causing more practically-oriented students to drop out. On the other hand, if the learning objectives of the fundamental knowledge and skills are not met first, it is difficult to proceed to solving complex engineering tasks. There is still much to develop when integrating these threads closer together.

Another question deals with the content of the Mathematics courses. The students enter the program with very different educational backgrounds and, especially, the varying mathematical competence seems to affect the first academic year significantly. Even though there is no clear evidence that the educational background would correlate with, for example, the drop out risk [6], the teachers experience significant differences in the students'

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competences [7] and, as discussed in this paper, the students' perceptions are dependent on the educational background. There is some tailoring of the courses based on the groups' background but the current curricular goal is to provide the same courses in Mathematics and Physics to all the students regardless to their educational background. Is this something that should be reconsidered? Should we provide different content to the different sub-groups? Would this make these topics more interesting (but not too difficult) to most of the students? How could the different students, not necessarily categorized by their educational background, be better supported in their steps towards professional growth than they currently are?

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Mathematical vs. Engineering Understanding: Engineering Students' Perceptions (Work in Progress)

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Abstract

In this article, the results of an ongoing study, which looks into how BSc engineering students at an academic college of engineering, perceive engineering and mathematical understanding, will be conveyed.Eighteenstudents ofa course called "Technique, mathematical understanding and what is in between them" participated in the study. The course was taken as part of theirGeneral Studies program. The research tool is a questionnaire given during the first lesson of the course, which was analysed according to qualitative methodology. As to mathematical understanding, most of the references made by the students were in regards to the technical aspects of the subject at hand. In addition, the affective aspect of mathematical understanding stood out from the responses. Engineering understanding is usually perceived by the students as the comprehension of complex processes, which requires deep knowledge, a high level of cognitive abilities, and an application of the studied knowledge to various fields.

Keywords: *Understanding, Mathematical Thinking, Engineering Thinking*.

1. Introduction

The subject of mathematics has always existed in the very core of engineering education. Engineering students take many courses in mathematics during their qualification for an undergraduate degree in engineering. Nevertheless, a literature review of academic journals in the area, as well as a thorough search using google scholar, revealed no articles regarding engineering students' perceptions as to the nature of mathematical understanding, nor regarding engineering understanding - the similarities and the differences between them.

2. Theoretical background - Mathematical and engineering understanding

In an age of information explosion, information aging, information accessibility and information relativity, there is no point in teaching information. Instead, it should be taught how to deal with information. Thus, as early as the 1980s, teaching for thinking has become the "trend", while teaching information has become "passé" [1]. The distinction between thinking and understanding is not conclusive, nor is it the focal point of this paper. One of the claims is that understanding is a prerequisite for good thinking [1].
Many researchers in the area of mathematics education define and emphasizethe importance of the subject of understanding. As early as 1976, Skemp mentioned the concept of understating and claimed that to understand a concept is to place it in the appropriate scheme, which is the mental structure in which one's knowledge is organized. The researcher spoke of an "instrumental understanding" versus a "relational understanding". The former is "knowing what to do", while the latter is "knowing why" [2]. We can find similar concepts in Hiebert [3]. He spoke about procedural versus conceptual knowledge. The lines separating these two types of knowledge are not conclusive. We define conceptual knowledge as a connection-abundant type of knowledge. Accordingly, a piece of information is only considered a part of the learner's conceptual knowledge if he recognizes its relation to the other information fragments connected to it. Procedural knowledge contains symbolic representations of concepts and subjects, rules, algorithms and procedures, which come into use in problem solving. According to the researcher, the two kinds of knowledge are important in learning and understanding mathematical subjects, and have a complex interaction. Michener [4] claims that in order to understand a mathematical item in a deep way, one must know about the item itself; its intra-space relation to other items of the same type; its inter-spacerelation to other items of different types; its dual relation to other items of like type; and its relations to items in others theories. Within the framework of understanding, the writer puts a special emphasis on the importance of understanding the connections between different mathematical concepts and ideas, as well as on the ability to

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perceive the greater context of the concept or theory that one wishes to understand. In addition, the writer attributes a great deal of importance to the level of independence and activity of the learner. A learner with high "mathematical maturity" is more independent, more active, and more likely to ask questions and to research subjects. We can find a similar claim in Sierpinska [5], who asserts that students' understanding is very passive, unlike that of professional mathematicians, which is much more active. Mathematicians do not only solve given problems, but also ask questions and have a kind of "sense" as to why and when they ought to use different approaches.

In summation, we can see, from the limited review of the main works dealing with mathematical understanding, that it correlates strongly with the learner's ability to answer the question "why?"; to place the knowledge within a wide and stable scheme; to recognize varied connections between subjects, representations and different solution strategies; as well as with the learner's independence and activity.

Unlike the subject of mathematical understanding, the subject of engineering understanding was not so thoroughly researched. A literature review discovered very few papers, which deal with the subject of engineering understanding. Sean, et al [6], for example, uses Hiebert's terms, and claims that in comparison with mathematical conceptual understanding, engineering conceptual understanding still requires a definition for each field of engineering. Most of the studies conducted in the field of engineering education refer to the concept of engineering thinking. Waks, et al. [7] conducted a comparison between engineering thinking and thinking in exact sciences such as physics, chemistry and astronomy. They pointed out common characteristics of the two, such as the creation of a knowledge base in the educational phase, and the use of creative and algorithmic routine thinking in the course of problem solving. The researchers claimed that the main reason for the difference in the cognitive processes of thinking in these fields emanates from the difference in their aims. In science, one begins with a body of knowledge in order to start a research. In contrast, in engineering, the starting point may be made up of heuristic considerations. Scientific research requires abstract thinking, while engineering usually calls for concrete thinking. In scientific research, we look for a general solution, which applies in all cases, while in engineering we look for a specific and optimal solution. In the sciences, the thinking process advances towards the unknown, while in engineering it progresses towards the desirable.

In their research, Cardella & Atman [8] examined how engineering students actually use mathematics in their practice. They found that engineering students make use of learned mathematical terms, such as integral, derivative, etc.; of problem solving strategies; of learned writing methods and mathematical representations; and of mathematical language and analytical thinking. The researchers' findings led them to the conclusion that mathematical thinking plays a central role in every aspect of engineering design. Thus, they claim that in order to better engineering students' performance, the bond between mathematical thinking and the practice of engineering must be strengthened.

3. The Research setting

The presentstudy took part at ORT Braude Academic College of Engineering. The eighteen research participants were students who took a course called "Technique, mathematical understanding and what isin between them", as part of a General Studies program. The students that participated in the course came from different engineering programs– electrical and electronic engineering, software engineering, industrial engineering and management, biotechnology engineering and mechanical engineering. The students' ages ranged from 20 to 25 years old.

3.1. The research aim and tools

The aim of the study is to explore how BSc engineering students at an academic college of engineering perceive engineering and mathematical understanding. The research tool is a questionnaire given during the first lesson of the course, and analysed according to qualitative methodology.

The questions included in the questionnaire andaddressed in this article were as following:

1) Today, in calculus lesson, we learned about the mathematical term "limit of a function". I had trouble understanding the term, and returned to my dorm room frustrated. My roommate, Danni, who will be graduating this year from college with a degree in engineering, claimed that he understands it perfectly and that he can help me. What questions would yousuggest I ask Danni and what aspects of the term should Iexamine in order to verify that Danni indeed understands the subject perfectly? Please address as many aspects as you can and elaborate.

2. A) Give an example of a mathematical subject that you understand. How do you know that you understand it, and what, in your opinion, aided your understanding it?

B) Give an example of a subject in engineering that you understand. How do you know that you understand it, and what, in your opinion, aided your understanding it?

3. A) Give an example of a mathematical subject that you do not understand. What, in your opinion, prevented you from understanding it, and what would have aided in understanding it?

B) Give an example of a subject in engineering that you do not understand. What, in your opinion, prevented you from understanding it, and what would have aided in understanding it?

4. Findings

4.1. The students' perceptions of mathematical understanding

The analysis of the students' answers revealed that the subjects relate to four different aspects of mathematical understanding: technical, conceptual, applicable and affective.

Technical aspects related to mathematical understanding:

Many answers, which included technical aspects that relate to mathematical understanding, were found (questions 1, 2.A, 3.A). For example, in question 1, technical aspects were found in 6 out of the 14 answers given. In question 2.A, they were found in 5 out of 13 answers, and in question 3.A in 4 out of 12 answers.Examples of technical aspects in answers dealing with mathematical understanding are:

"I do a lot of exercises and check my answers in order to understand."

"Practicing the subject aids in understanding it better."

Conceptual aspects related to mathematical understanding:

Aspects connected with the understanding of the subject (conceptual aspects) were found in the students' answers. For example, in question 1, references to conceptual aspects werefound in 5 out of the14 answers given; in question 2.A in 3 out of 13 answers, and in question 3.A, in 2 out of 12 answers. Examples of conceptual aspects in answers dealing with mathematical understanding are:

"I would ask Danni what the meaning of "limit of a function" is."

"Writing questions on the subject aids me in understanding it."

"Different representations of the subject help [in understanding] – algebraic presentation, graphic presentation…"

Applicable aspects related to mathematical understanding:

Afew aspects that refer to the applicability and relevance of mathematical understanding in everyday life (applicable aspects) were also found. For example, such references were found in 4 out of the 14 answers given to question 1. No such references were found in answersto question 2. In question 3.A we found them in 2 out of 12 of the answers given. Examples of applicable aspects in questions dealing with mathematical understanding are:

"I would ask Danni what the uses for the concept "limit of a function" are, and in which fields it is used."

"I didn't understand the subject because it is difficult to see the practicality and the use of the learned material, aswell as its ramifications on reality."

Affective aspects relatedto mathematical understanding:

Another interesting finding that especially stood out in question 3.A is a motivational aspect and an attitude towards the subject of math. As can be recalled, in question 3.B we asked the students what prevented them from understanding a certain mathematical subject. In 5 out of the 12 answers given, an aspect stood out which gives lack of motivation or lack of a personal interest in the learned subject, as one of the explanations for the lack of understanding.Examples for affective aspects in questions dealing with mathematical understanding are:

"I couldn't relate to the subject matter. I didn't try to understand it."

"I didn't put any effort in."

This aspect was less prominent in the questions that dealt with engineering understanding.

4.2. The students' perceptions of engineering understanding

The analysis of the students' answers revealed that the subjects are mainly related to three different aspects of engineering understanding: technical, conceptual, and applicable. The affective aspect was mentioned in only two answers.

Technical aspects relatedto engineering understanding

Technical aspects of the subject were found in answers toquestions 2.B and 3.B. In question 2.B technical aspects were recognized in 5 out of the 13 answers given, and in question 3.B we found them in 2 out of the 12 answers given.Examples of technical aspects in answers dealing with engineering understandingare:

"Solving a lot of exercises on the subject helps me [understand]."

"I couldn't understand it because all we learned was the technique."

It is worth mentioning that in regards to engineering understanding, and apart from the answers dealing with mathematical understanding, we found two answers to question 3.B in which the students state that their lack of understanding of the engineering subjects stems from the technical teaching method. They explicitly say that practice and technical teaching alone are not enough to understand the subject matter in the field of engineering.

Conceptual aspects related to engineering understanding

Aspects connected with understanding the subject (conceptual aspects) were also found in questions dealing with engineering understanding. In question 2.B, references to conceptual aspects were found in 3 out of the 13 answers

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given, and in question 3.B in 2 out of the 12 answers given.Examples of conceptual aspects in answers dealing with engineering understandingare:

"The very fact that we deal with the subject from a theoretical angle, connecting the mathematical to the practical aspects, performing experiments and creating a system, have contributed to my understanding."

"Healthy logic and a mathematical understanding of the subject that has to do with calculus aided me in understanding."

Applicable aspects related to engineering understanding

In addition to technical and conceptual aspects, a few applicable aspects werealso found in the students' answers.We found such aspects in 3 out of the 13 answers given to question 2.B.Examples of applicable aspects in questions dealing with engineering understanding are:

"Seeing the need for the subject in the field aids me in understanding it."

"Seeing the subject in reality and in life helps me understand it."

The aspect that has to do with the attitude towards the subject matter did not stand out in the answers that dealt with engineering understanding, as they did in the ones that dealt with mathematical understanding. One such aspect can be seen in the answers to question 2.B and in an answer to question 3.B: "A personal matter aided me in understanding the subject." Here, unlike in answers dealing with mathematical understanding, we can see a positive approach to the subject that can also help in understanding it.

5. Preliminary conclusions and planning the continuation of the research

The article presents preliminary results of an ongoing study.The analysis of the students' answers revealed that the subjects relate to four different aspects of engineering and mathematical understanding: technical, conceptual, applicable and affective. The technical aspect matches Skemp's concept of "instrumental understanding" [2], and Hiebert's concept of procedural understanding [3]. The conceptual aspect corresponds with Skemp's relational understanding – as well as with Hiebert's conceptual understanding [2]-[3]. This aspect was referenced in two kinds of mathematical and engineering understanding. Both the technical and affective aspects were more prominent in the context of mathematical understanding. For example, five students pointed out a lack of motivation and a lack of interest as reasons for not understanding a mathematical subject. None of the students mentioned above pointed out a lack of motivation in engineering subjects.

Later on in the research, the researchers intend to pass a similar questionnaire at the end of the course. The answers to the second questionnaire will be analysed and we will try to see how and whether being exposed to the course's subject matter contributed to the development of the engineering students' conceptions of mathematical and engineering understanding.Additionally, the authors plan a longitudinal study with the aim to deepen and broaden the insights of the research subject. The study will probably involve both qualitative research tools and quantitative research methods.

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Problem-Based Learning as a Strategy for Teaching Mathematics at Northwest La Salle University

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Abstract

Learning of mathematics represents a challenge throughout university study program. Within a range of methodological approaches available for the learning, highlight the focus on competencies and active methodologies such as Project-Based Learning and Problem-Based Learning (PBL). In this paper the application of PBL is presented in a matter of vectorial calculus. Learning is organized around a problem learning trajectory and transferred to a real situation in which students had to generate and select options for designing a simulator in MATHEMATICA software. To design it, they worked as a group and decided to use graphs, functions, differential and integral calculus, vectors and methods of polynomial interpolation. The results show that the technique of PBL was useful in the learning process, as it promotes creativity, critical thinking, managing complex situations, promote research and collaborative work.

Keywords: *Focus on competencies, Problem-Based Learning, Mathematics.*

1. Introduction

In recent years, the issue of competence in mathematics has become increasingly important and has been taken up at the highest policy level. Mathematical competence has been identified as one of the key competences necessary for personal fulfilment, active citizenship, social inclusion and employability in a knowledge society [1]. Acquiring a mathematical competence involves: a database accessible knowledge, self-organized and flexible, heuristic methods, meta-knowledge, positive beliefs about discipline and self-regulatory skills; implies that the student is able to transfer skills and knowledge to new tasks and learning environments [2]. Students must demonstrate understanding of concepts, mathematical operations and relationships; must be skillful for flexible processes, accurately, efficiently and appropriately; must demonstrate ability to formulate, represent and solve mathematical problems and to think, reflect, explain and justify logically [3]. The inclination to see mathematics as sensible discipline, useful and valuable is important as well as trust in knowledge and skills [3]. Learning math is not reduced to the memorization of rules and procedures or learning knowledge isolated from each other; involves acquiring knowledge, skills, attitudes and habits [4].

In Mexico, as in many parts of the world, learning mathematics represents a challenge for engineering students, mainly because of the lack of context and application in the first semesters of studies. In order to the computation, learning occurs in contradictory framework, it is submitted that this is the basis for future professional development engineer; however, his teaching has been formalized through the use and abuse of algebra, and has even arithmetized in the exposed framework [5]. Because of this, learning calculus tends to have a high level of contextualization and disarticulation with respect to the remaining racing courses (particularly of Engineering), which requires the learner to perform the titanic task of being the one who seeks to integrate various skills learned as a whole, something that is obviously not easy to achieve [6]. Against this, has emerged the option of learning and teaching resume calculation based on the historical origins of the discipline, so that this will contribute to solving problems related to the nature and optimal use of resources [7]. Thereby, it is critical that the teacher who teaches calculus reflect on the problems that both students as himself facing to be able to determine possible causes and project consequences, and so redefine its role, since depending on the perception of their own work, can induce the learner to see in mathematics a formalized resource that stands on its own, or an instrument to solve problems, leaving the formalities for professional mathematicians [6].

The learning of mathematics, beyond how to expose by the teacher, should be driven by educational strategies designed within modern educational approaches, such as the Competency-Based Education. In this approach, students and teachers take different roles to traditional education. The students take control of their learning while the teacher becomes a facilitator more than a dominator teacher and expositor of the issues. Active methodologies integrated approach competencies are being used in engineering education [8] and mathematics [9], mainly Problem Based Learning (PBL) and Project Based Learning (BLproj). These two active methodologies adapt naturally to the learning of engineering. In the case of mathematics, especially to learning calculus, PBL and BLproj must be accompanied by projects that motivate and challenge students, and especially to allow linking other knowledge or, if necessary, construct new knowledge.

In this paper is presented the application of active methodology Problem Based Learning in a subject of vectorial calculus taught in the fourth semester to the students of engineering at Northwestern University La Salle. Learning two competency units of matter was organized around a trajectory problem.

2. The competency model in Northwest La Salle University

Currently are showing accelerated and profound changes in society which brings significant new challenges for higher level education, such as school link with the productive sector through joint realization of projects; break the encyclopedic education; incorporate learning environments and experiences that enable participants in the process of learning to access the knowledge society, among others. An alternative to respond to these challenges and has been accepted at the global level is the educational model based on skills [10].

Considering this context, La Salle University Northwest since its inception believes in its mission the comprehensive training of students, and to strengthen relevant training to new contexts, adds to its curriculum model socioconstructivist the skills approach in the 2011; understood competition *the interdependent set of knowledge, skills, attitudes and values (attributes) that integrates students in order to solve problems in their personal and professional skills for social transformation* [11]. The above results in a change in the role of the student and the teacher. The student becomes an active subject of their own learning, ie, develops, interprets and makes sense of the information you present under positive external conditions. The student is ultimately responsible for their own learning. Also, this educational model causes a change in the teaching role, which becomes a mediator that focuses on the learning processes of students, they learn more and they alone, or in dialogue or discussion group without depend on it, are able to organize, reason, communicate ideas, thoughts and experiences. This new role of the teacher implies that implements strategies where the student is the main actor in the pursuit of knowledge to solve situations that arise.

To apply this socioconstructivist model with focus on competencies La Salle University Northwestern University Professor requires a professionalization of teaching, through constant training and updating their skills, thus, founded La Salle University Northwest construction and implementation a diploma in teacher training skills in blended mode of education, divided into 8 modules. The central themes include the contextualization of the curriculum model and the specific characteristics of being Lasallian (Philosophy of the La Salle University); fundamentals translate theory into classroom teaching practice including teaching strategies, learning assessment and planning processes of teaching and learning; and teaching skills required to implement the curriculum model. One of the modules of the graduate promotes the use of active methodologies as a strategy to systematize the learning in the classroom.

Apprenticeships obtained the diploma have been applied in different curricula, particularly in engineering studies. For example, in [12] methods Problem Based Learning and Project Based on the matter imparted to students studying Mechatronics and Industrial Design Learning Mechanisms were implemented. In [13] presents an experience of applying ABProy in matters of Research Seminar and mechanisms in the development of a Cartesian robot.

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3. Considerations for Based Learning Problems

Since the inception of the late 1960s, the PBL (Problem Based Learning) approach has a history of over four decades. Gradually, the value of PBL has been recognized and documented in a number of researches. PBL seems to surpass traditional education approaches in terms of promoting students' skill development (e.g. communication skills, problem solving skills, critical thinking), motivating students to learn, as well as fostering students' lifelong learning attitude, etc [14].

Problem Based Learning (PBL) unlike traditional learning actively engages the student in the construction of knowledge where the role of the tutor is to guide and challenge students rather than to transmit knowledge. An essential aspect of PBL is feedback and reflection on the learning process where group dynamics are central components to the creation of knowledge. Learning is therefore a self-regulatory process of dealing with the conflict between existing personal models of the world and new insights an individual encounters, being the reconstruction of new representations of reality, meaning making and its negotiation through cooperative social activity, discourse, and debate. It has also been argued, that PBL is not a particular way or method of learning but rather one that takes on a variety of forms [15]. PBL is a process of meaningful and experiential learning that helps students to become active learners by providing them with real world problems to resolve [16]. Not only PBL aims at promoting student centered learning and enhancing the development of students' higher order thinking and fostering students' social skills [17], it can also help in developing thinking skills through solving problems [18].

The phases of ABP are not unique. For example in [19] proposed the following phases:

a) choosing your topic, b) determining objectives, c) writing the problem statement, d) preparing for deep questioning, e) anticipating learning issues, f) determining resources, g) assigning students, and h) putting PBL into action.

In [20] the development process ABP follows is proposed: 1. Read and analyze the problem scenario; 2. Conduct a brainstorming; 3. Make a list of what is known; 4. Make a list of what is not known; 5. Make a list of what needs to be done to solve the problem; 6. Define the problem; 7. Get information; and 8. Present results.

4. Description of the experience

This section is the experience of the application of PBL in a vectorial calculus subject described. Some relevant data about the problem solved and educational data is provided below.

4.1. The problem

In relation to the problem to be solved, the teacher before the start of vectorial calculus subject, made a practice in the laboratory concerning the drilling of a piece on a CNC lathe (Lathe of Computer Numerical Control). Drilling operations were observed by students and explained by the teacher. The aim of the practice was the presentation of an industrial application whose operation could be modeled and simulated with the knowledge you acquire during the course. Drilling description was as follows: a cylindrical part is mounted on the chuk of a CNC lathe then would perform a drill drilling the last piece automatically in three stages. The central idea of the problem was the simulation of the movement of the tool on the trajectories of the hole.

4.2. Planning

The planning problem is performed taking into consideration the teacher's experience in industrial applications and content of the curriculum. In the case of the problem of trajectory following aspects were considered:

1) Due to the teacher's experience around the problem, two units of competency matter of vectorial calculus, one related to vectors and operations, and the other associated with vector functions and their derivatives are considered.
2) It is required the knowledge of polynomial interpolation. These issues would be achieved under recall since they had seen in other subjects.
3) The problem required fundamentals of particle physics, which would be acquired under reminder, as had been seen by students.
4) It was necessary programming skills to simulate the movement of the tool. The basics of programming already been seen in previous classes, or whether new knowledge is required extraclass these would be acquired in courses.

It is noteworthy that the group of students of vectorial calculus consisted of 20 students of the School of Mechatronics of fourth semester.

4.3. Application of PBL

Before applying the steps of PBL, the teacher and the students agreed on the following aspects:

1) The project consists of four teams whose organization was under the responsibility of the students would perform.
2) The organization and work planning would be the responsibility of the students and the teacher only be limited to providing guidance on the development of the problem.
3) The teacher would provide the basic knowledge of each competency unit of matter and students translate the knowledge needed to solve the problem.
4) The way to qualify was agreed as follows: 1) During the process (exams per unit of competence, attendance at counseling, participation in classes) and 2) Final (final exam, final draft written, functional product , final presentation, executive summary. in few instruments evaluation rubrics, checklists and rubrics were considered peer.

The first step of PBL is ***to read and analyze the problem scenario*** [20]. In this step, as mentioned above, students practice drilling observed in a CNC lathe. Previously, the teacher gave them directions to mean paying more attention to the movements of the tool. Once the practice session the teacher gave about the paths in particular the particle motion. The students made the right questions about what would be in the class of calculation in relation to what they saw during the drilling process. The idea was to mimic the movements of the drill in the drilling operation.

The second step concerns the ***realization of a brainstorm about the problem at hand***. Students discussed ways of developing the simulator, particularly the type of computer platform that would be used and ways to design, modeling and programming the movement of the operation related drilling tool in stages.

Later, the students made a ***list of what is known***. This list was as follows: 1) Knowledge of particle physics, 2) Knowledge of programming and 3) differential and integral calculus. This information only had to remember since they had acquired in previous courses to matter vectorial calculus.

Once enlisted the known knowledge, students made a ***list of what is not known***. The list was as follows: 1) knowledge and mastery of a formal calculus platform for programming and simulation of the drilling process, 2) The methodology for mathematically modeling the trajectory, 3) Knowledge of Vector Calculus that would be required for modeling trajectory.

Having made a documentary research articles, theses, and Internet documents about the history, students proposed a ***list of what needs to be done to solve the problem***. The list was as follows: 1) To design the geometry of the loci of the path, 2) design a profile or chart speeds, 3) generate the equations of motion, 4) Generate the kinematic functions from the proposed profile 5) Analyze the continuity of the kinematic functions, 6) To propose an interpolation method, 7) Integrate the equations of the loci with the kinematic functions, 8) Programming models and 9) simulate the movements of the hole.

The next step was to ***define a problem***. Students described the problem as follows:

Known operating speeds (initial and cutting), times, distances, points of tool path, find:

1) The configuration of the loci tool path.
2) The velocity profile and its associated function.
3) Displacement and acceleration profiles and their respective graphs.
4) The mathematical models of the trajectory.
5) Motion simulator.

Having described the problem, students ***got the information***. The development of the problem was as follows: Students discussed various proposals on the configuration of the loci of the trajectory and velocity profile. These two configurations are the foundation drilling simulator. Figures 1 and 2 show the locus of drilling movements and explanation, and Figure 3 shows the velocity profile proposed by students.

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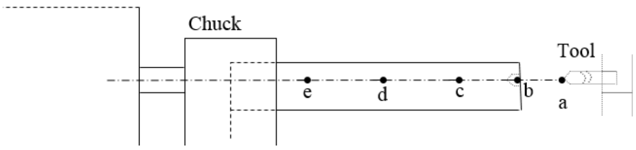


Figure 1. Description drilling stages.

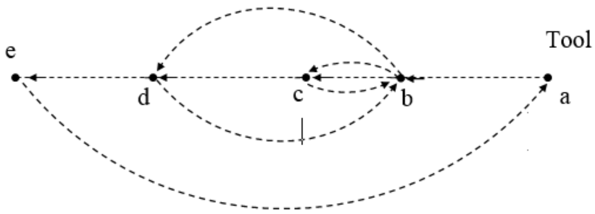


Figure 2. Description drilling movements.

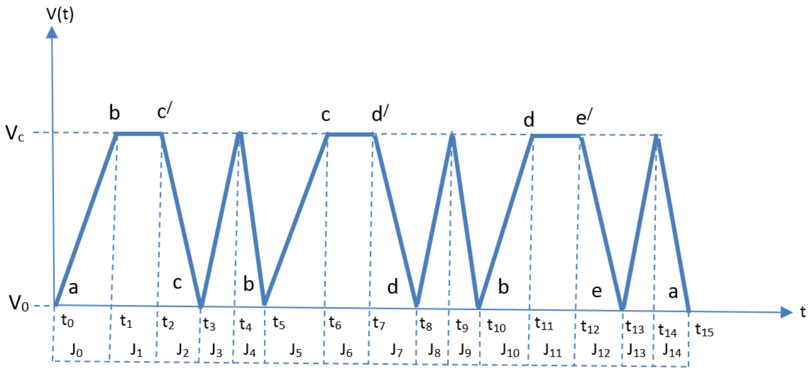


Figure 3. Velocity profile.

The drilling process is performed by stages as follows: a drill bit is located at point **a** (see Figure 1) then moves from point **a** to point **b**. Without dwelling on the point by **a** cutting speed (Vc) the bit makes the first drilling on the straight line **bc**. At point **c** the tool stops (Vo) and returns to point **b** to download burrs. Subsequently, the tool moves from point b to point **c**. Without stopping short drill the workpiece material on the line **cd**. In d the drill stops and returns to point **b**. Finally, the tool moves from point b to point without stopping dy third drilling operation on the straight line is made and returns to the point. Drilling operations are performed in **bc, cd** and **de** sections (see Figures 1, 2 and 3). Once the velocity profile proposed, students proceeded to develop mathematical models of velocity, displacement and acceleration. The models were programmed in MATHEMATICA platform formal calculus. The graphs of velocity (V(t)) and acceleration (A(t)) are shown in Figures 4 and 5.

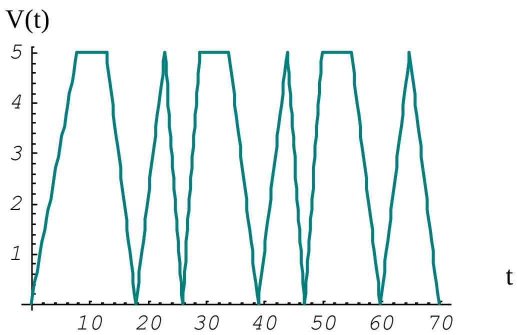


Figure 4. Chart speed.

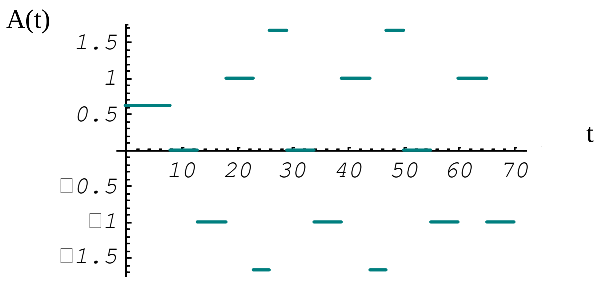


Figure 5. Graph of accelerations

Students visualized discontinuity profile accelerations and proposed using polynomial interpolation to eliminate discontinues. Figure 6 shows the interpolated stretch **cb** (see Figure 3).

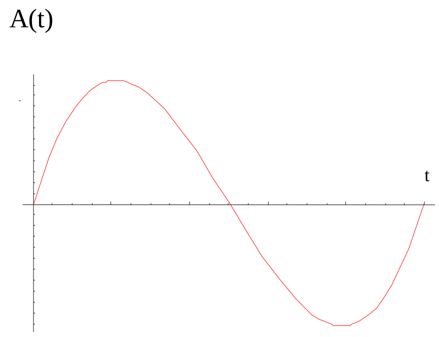
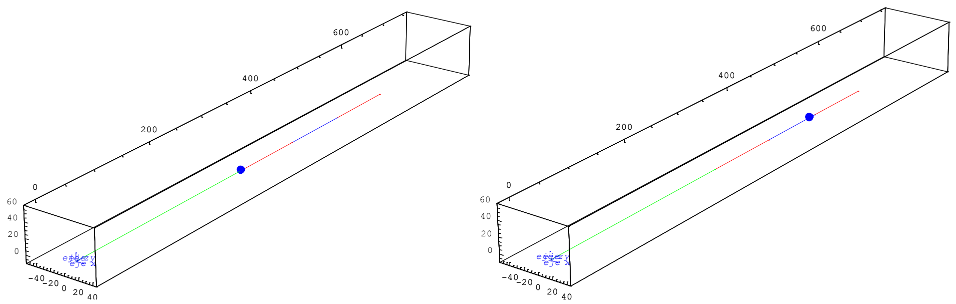


Figure 6. **cb** section of the graph of interpolated acceleration.

The last step of ABP is the ***presentation of results***. In this step the students combined their whole development and information generated for drilling simulator in MATHEMATICA software. Figure 7 shows a small sphere that moves along the linear path loci. The sphere moves to the profile of theoretical speeds and interpolated.



A) B)

Figure 7. Graphical output drilling simulator. A) Start of the first phase of drilling, b) Start of the third stage of drilling.

Finally, it is noteworthy that the Mathematica software is used by engineering students since its syntax is simple and has many applications in physics and mathematics. Table 1 shows some of the code in Mathematica programming related to polynomial of degree 5 for smoothing trajectory profiles.

```
Clear[alfa0,alfa1,alfa2,alfa3,alfa4,alfa5];
Sol2=Solve[Ecuaciones[t1,t2,0,dist2,vel1a,vel2a,acel1,acel2],{alfa0,alfa1,alfa2,alfa3,alfa4,alfa5}]//Flatten;
{a0j2,a1j2,a2j2,a3j2,a4j2,a5j2}={alfa0,alfa1,alfa2,alfa3,alfa4,alfa5}/.Sol2;

Polj2=a0j2+a1j2*(t)+a2j2*(t)^2+a3j2*(t)^3+a4j2*(t)^4+a5j2*(t)^5
Polj2p=D[Polj2,t]
Polj2pp=D[Polj2p,t]
```

Table 1. Example of code in Mathematica.

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5. Conclusion

This paper presents the application of PBL in a material Vector Calculus. The main conclusions are summarized in the following points:

- The ABP is an active methodology that can be used for teaching and learning of mathematics, mainly because it promotes active and collaborative learning. Regarding the matter of vectorial calculus, the APB allowed to drive and systematize the development of a problem whose solution represents a challenge and a motivation for students, and allowed the creation of new knowledge from other knowledge integration as physics, programming and mathematical topics from previous courses.
- The selection of the problem and the teacher's experience is crucial for the implementation of PBL. The simulation of multiple drilling was an interesting problem for students, since he found meaning to mathematical concepts such as vectors, vector functions, vector derivation, interpolation matrices and solving linear systems, as well as particle physics.
- The role played by the student in the PBL allows you to understand that learning depends on their active participation in working groups, and is primarily responsible for the acquisition and practice of knowledge.
- The traditional learning of mathematics, especially of vectorial calculus, is usually based on problem solving, and evaluations are conducted by examinations. When the PBL is applied to the learning of mathematics, students not only solve problems, but they also develop skills to formulate and solve applied problems, where the knowledge they learn generally have a meaning with the reality and also the instruments of evaluation are diversified.
- The PBL can use various mechanisms to evaluate the performances, and ignores the central role played traditional exams in mathematics education. The operation of the simulator as a final product was motivating for students and had a weight of 50% on the rating of the subject.

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Using Educational Technology to Enhance Mathematics Learning

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Abstract

Mathematics is one of the most important skills for future engineers. Hence, special attention to mathematics education should be paid in all levels of education. However, due to scarce teacher resources and growing class sizes the possibility for personal tutoring is often hardly enough, especially for weaker students. We have developed an educational tool called ViLLE, with support for automatic assessment and immediate feedback for assignments. Despite being originally designed for programming exercises, the tool nowadays offers various exercises designed for mathematics education in all levels from elementary schools to universities. In this paper, we describe the automatically assessed exercise types designed for mathematics education. First, the design principles and the pedagogic background are illustrated. Next, the technical implementation is discussed as well as some challenges. Finally, we present some use cases on the various levels of education, with main focus on university level mathematics course. Results and feedback from student are reported and analyzed, following with our experiences and conclusions.

Keywords: *Educational technology, Mathematics, Student performance*

1. Introduction

Computers, whether they are mobile devices or desktop computers, have become more common in our lives. Computers and information technology are also becoming increasingly common in schools and as a part of our teaching. In Finland the matriculation examination is being transformed into electronic form starting in 2016 with subjects that have fewer participants and all the subjects are supposed to be electronic by 2019. The electronic matriculation examination will require upper secondary schools to increase the amount of computer assisted learning (CAL) in order to make sure that students have the necessary skills to do well in the examination. Mathematics is one of the last subjects to be converted into electronic form. There are numerous studies that support CAL and show that CAL increases student engagement and thus improves learning results and motivation [7, 13]. There are also numerous studies looking more closely into learning mathematics using computers ranging from small children to university level students with similar results [6, 11, 3, 4].

At first we will take a look into previous research in the field of computer assisted mathematics learning. After that we will describe the design principles used in electronic math exercises. The math exercises types available and developed for ViLLE are described in more detail in the Section 3. We will present two cases, where CAL was used for mathematics learning. The first case covers usage of ViLLE in first grade mathematics and the second case covers a refresher course arranged in the beginning of undergraduate studies. In both of the cases we will report details of students' time usage and submission behavior. We will also discuss the challenges encountered while designing and implementing the exercises and challenges reported by students or teachers in study groups.

2. Related Work

There seems to be more research on using CAL in mathematics in primary education than in upper secondary level or at university level. This might be due the fact that in lower level mathematics writing, answers require only typing numbers instead of complicated equations. Basic arithmetic problems are also a lot easier to generate than more complex math problems.

First we are going to take a look into kindergarten and primary school level research on CAL. A research group in India tested the effectiveness of supplementary CAL in a randomized experiment. There were 111 schools altogether participating in the experiment and 55 of them were treatment schools. Students in the treatment group were provided two hours of shared computer time per week with another student. Students from the treatment group increased their math scores on average by 0.37 standard deviations [11]. The positive results from this study is no surprise, considering that CAL was supplementary. Nevertheless it shows a clear indication that using CAL, we can improve learning results, even if the conditions and resources are very different in India than what we are used to dealing with when talking about CAL.

Räsänen et al. [12] conducted a research with two educational games, Number Race and Graphogame-Math, aimed for children in kindergarten. The goal of these educational games is to improve children's number skills. 30 children out of 350 were selected as a treatment group. The rest of the children acted as a passive control group. Each child in treatment group had low numeracy skills, while children in the control group had normal math skills. The Number Race -game was designed to deal with relations and comparing numbers, whereas Graphogame-Math focused on matching small symbol groups to exact numbers. The 30 children in treatment group were allocated to two groups, one playing Number Race and other group playing Graphogame on daily basis for three weeks. Both groups improved their skills in number comparison, although not on all children. The research team concluded that playing educational games does not suit well for all children. They also mentioned repetition as one of the main reasons for increased performance among the treatment group [12]. Even without a proper treatment group, this research showed some very promising results of the impact of CAL on learning performance.

Fuchs et al. [5] have also studied the usage of CAL with students suffering from math and reading disability. 16 first grade students received three 10 minute sessions over a period of 18 weeks. The aim of the treatment was to automate addition and subtraction with numbers from 0 to 10. Students improved their addition skills but failed to improve their subtraction skills. There was also no transfer of addition skills to word problems. There was unfortunately no control group to further verify these results in this research setup. Even though the effects on addition skills were positive and students were at-risk students, the results still raise a question about why was there no effect on subtraction.

We have previously conducted research on computer assisted learning using ViLLE with third graders and first graders [8, 9]. We did a preliminary research on automatic assessment, immediate feedback and using visualization to test how it affects the learning of fractions and decimal numbers with 18 third graders. This was a short one-lesson experiment. The third graders enjoyed CAL and their learning performance increased statistically significantly, even though there was no control group to verify the results [8]. As a follow up, we conducted a ten week long experiment on two first grade classes in a Finnish school. One of the classes acted as a treatment group (N=23) and the other one as a control group (N=21). One mathematics lesson per week was converted into an electronic lesson using ViLLE. Students

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were tested before and after the research. The treatment group increased their learning performance significantly over the control group in the post-test. We were able to increase the amount of work that the students did during the lesson and at home as homework with the aid of automatic assessment, immediate feedback and game-like exercises [9].

Croft et al. [4] experimented on computer assisted assessment with first-year undergraduate engineering students. One of the goals of the research was to increase students' confidence and competence in routine mathematical techniques that are typically used in engineering. Almost 400 engineering students took part in the study. Overall feedback from the students was very positive and the students seemed to appreciate the flexibility that electronic exercises and automatic assessment provided. Students also stated that they worked harder with the help of computer assisted exercises. Research conducted by Croft's research team indicates clearly that using automatic assessment and immediate feedback we can increase the amount of work that students put in their studies. These results also indicate that students are willing to work harder, if we hand them the right tools to let them do self-evaluation and means to find out where they need more practice.

In the light of these research reports, it seems that learning games coupled with immediate feedback increase student engagement, motivation and learning performance.

3. Mathematics Exercises

3.1. Game-like exercise types for primary school

We have developed various game-like exercise types in an educational platform called ViLLE (see [10]) that can be used in primary school mathematics. The general feedback from students and teachers concerning these game-like exercises has been very positive. In various unofficial surveys students have raised game-like exercises as their favorite exercises. These exercise types can be used to drill various topics from basic arithmetic facts to multiplication and parity of numbers. The three most used game-like exercise types are a rally game, a ladder game and a flying calculations game. Each exercise type has multiple themes, which can be used to create diversity in exercises.

All three exercise types are basically multiple choice questions, where the question and answer options are user defined. In its simplest form the question is an equation and options are different answer options. Rally game has a fixed time limit in which the correct answer must be given by driving through the correct answer. In flying calculations, the time limit can be set by teacher. Ladder game doesn't have any time restrictions. All questions sets are interchangeable between these exercise types.

3.2. Upper secondary school exercises

The exercises that were built for more mature students had their main focus on immediate feedback, automatic assessment and problem visualization. These goals were selected to enable students to study autonomously, while still allowing them to be able to verify their own progress. As an example of such exercises, the following sections describe one exercise type: a Polynomial equation exercise.

3.2.1. Polynomial equation problems

Polynomial equation problems are of the form

$$\sum_{i=0}^{n} a_i \cdot x^i = \sum_{i=0}^{m} b_i \cdot x^i$$

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The difficulty of such problems is defined by the choice of *m* and *n*, as well as the magnitude and type of the roots of the simplified polynomial. For these exercises, the teacher can choose the roots' ranges, as well as their types. The roots can be either integer, rational, decimal or real numbers. Once the root types and their intervals are defined, problem sets can be generated automatically from the constraints.

While the preceding method allows generation of arbitrary polynomial problems, Finnish upper secondary school curriculum only handles extensively the linear and quadratic cases, where *m* and *n* are at most two. The quadratic cases are taught using the quadratic solution formula, and some teachers extend the usage of this formula to simple cubic cases by teaching how to apply variable substitution with small integer values to detect and factorize the simplest roots. Therefore, the above construction needs to be further extended to allow limitations for the cubic roots.

Due to the fact that the exercises can be generated from a set of constraints, the amount of available exercises is essentially unbounded, and the entire model solution can be immediately shared with the student without the risk of exploitation (see Figure 1). This eases the automatic teaching process, as the model solutions can be constructed directly from the roots, and shared with the student.

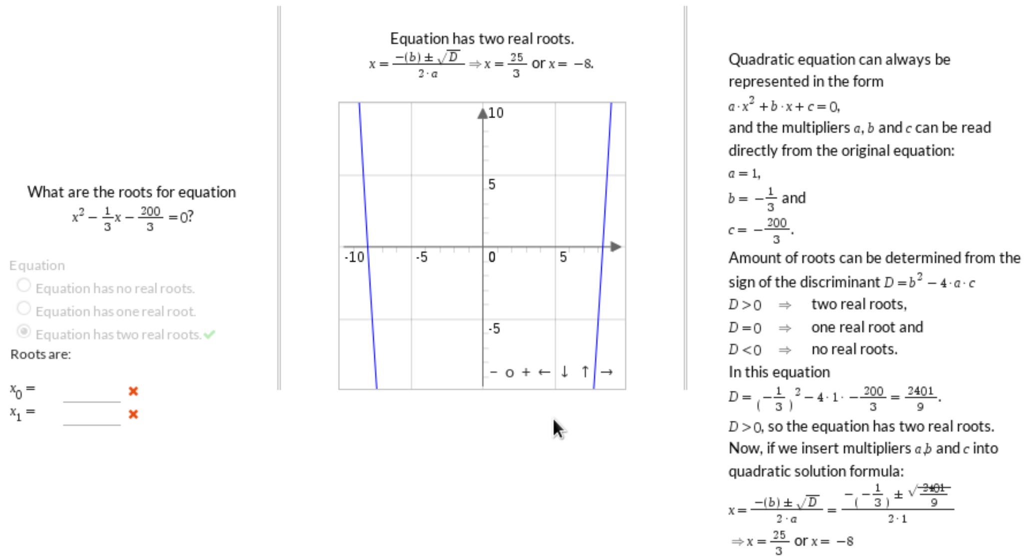

Figure 1. The Polynomial equation exercise and its automatic feedback, if the user answers incorrectly.

4. Research Setup

In this paper we present two cases where CAL is utilized in mathematics. In both cases we present the time usage and submission behavior of the students. The first case is elementary school mathematics from first grade, and the second case a university level upper secondary school refresher course.

4.1. Case 1

We inspected time usage and submission behavior of 21 first graders during a 10 week period. Student used multiple different kinds of exercise types during these weeks. The students used ViLLE for one lesson per week (45 minutes) and their homework was assigned into ViLLE. Learning performance of this group was examined previously in [9]. The results showed that with help of automatic assessment and immediate feedback we could improve students' learning performance significantly.

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4.2. Case 2

In the second case we inspected the time usage and submission behavior in an upper secondary school mathematics refresher course with 45 first year university student, eight of which have no submissions. The students on the course were mostly computer science majors, but there were small minorities from physics, chemistry and economics departments. The refresher course was arranged in the autumn of 2014 and it lasted for half a semester. The course was constructed so that it would contain large amounts of hands-on exercises compared to the amount of awarded study credits: In order to pass this course the students had to participate in at least ten out of thirteen 90 minute workshops and achieve at least 200 points out of 380 available points in ViLLE. Workshops consisted of exercise sets that were solved in small groups (~4 students per group), while ViLLE exercises had three large exercise sets, one about polynomial equations, one about inequalities and sign charts, and one about derivation rules. The sets had maximum scores of 100, 140 and 140 points, respectively. ViLLE exercises were exclusively solved outside the workshops. The students were awarded 2 ECTS for the course. The last of the three sets containing derivation exercises was considered very difficult among the students, and almost nobody successfully solved exercises from it.

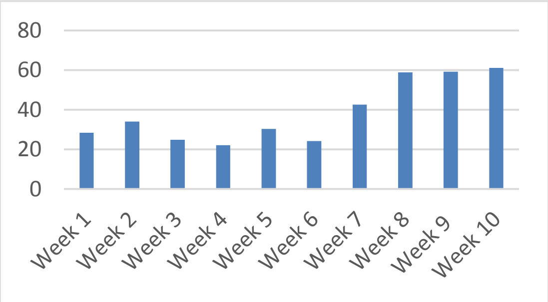
The students' math skills varied greatly throughout the course. The fastest students completed the exercise set in ViLLE within one day, while some struggled to score the required 200 points within the course time frame. Roughly, a third of participants passed the course.

5. Results

5.1. Case 1

The time usage (Figure 2, left) and submit behavior (Figure 2, right) of the students was observed on weekly basis. In the first lesson students got familiar with ViLLE and they already had their computers prepared. In the second lesson students were required to set up computers by themselves. Both charts in Figure 2 present class averages on each week. Null values were removed from the data. One lesson lasts for 45 minutes. The time usage report only takes into account time spent on working on exercises.

Even though students had to set up computer themselves on week 2, the time usage on exercises increased from week 1 and the submission count stayed about the same. After the second week, both time on task and submission count decreased, which might indicate that novelty of CAL had worn off.



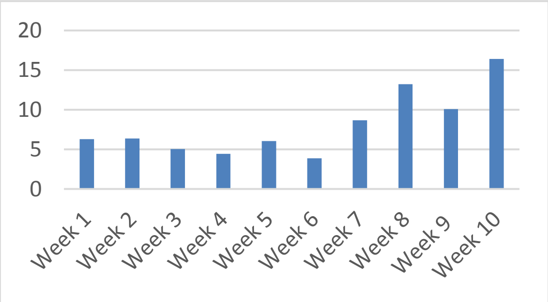


Figure 2. Left: Time usage per week in minutes. Right: Submissions per week

Both figures indicate that after week 6 the students started to work more on given tasks. After week 6 we changed the structure of the exercises. In the beginning students had a different set of exercises to work at school and another smaller set of exercises to work at home. Starting from week 7, these sets were combined into one set of exercises. This clearly motivated students to do more work.

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5.2. Case 2

On the university level upper secondary school refresher course, students were given three sets of homework assignments at the beginning of the course, and they were then told that they need to score at least 200 points in total from these given exercises in order to pass the course. Figure 3 depicts a sorted list of students' final total scores in ViLLE. The threshold for passing the course is clearly visible as an elbow in the plot. I t is also worth noting, that a large portion of the students have received the close to maximum score from the Polynomial Equation Exercise Set (mean=65.5), while only a relatively small proportion of points come from the Derivation Rule Exercise Set (mean=12.5). This is well in line with the student feedback that claimed derivation exercises to be too difficult

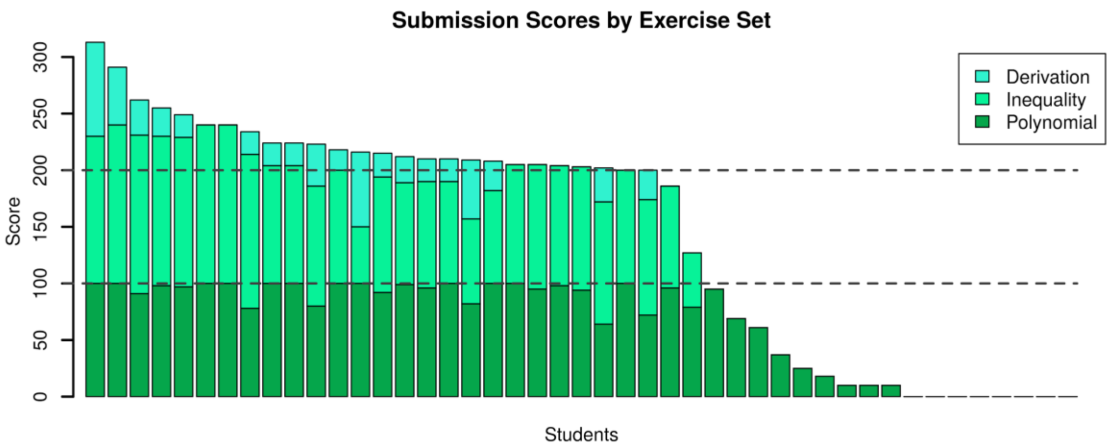

Figure 3. Students' submission scores by exercise set throughout the course from largest to smallest. The minimum required amount of points (200) is clearly visible as a threshold (see the upper gray dashed line). Similarly, almost all of the students have received the maximum amount of points from the easiest exercise type, Polynomial exercise type.

Figure 4 shows the total time usage by exercise set in ViLLE during the course. It is easily seen that the threshold effect that is visible in Figure 3 is not related to time usage on the homework. Similarly, the nearly perfectly solved Polynomial Equation Exercise Set has taken very different amounts of time for different students. The amounts vary between 50 and 170 minutes. It is worth noting that all of the students have used less than six hours on their homework, while the reserved amount of time is 27 hours.
While students have received nearly identical amounts of points from the Polynomial and Inequality exercise sets (means 65.5 and 65.8 respectively), students have spent a little more time doing the inequality exercises (mean 57 min) compared to the Polynomial ones (mean 50 min). This is a small difference compared to the average time spent, an average of 25 minutes per student, doing the Derivation exercise set. This raises the question about the level of difficulty compared to the level of reward. For Polynomial and Inequality exercise sets, an average student received 1.31 and 1.15 points per minute, whereas the corresponding figure for Derivation exercise is only 0.54 points per minute. Such a difference in reward per time unit is clearly apparent to the student, and the exercise is perceived as difficult.

The apparent difficulty of the Derivation Rule Exercise Set compared to the other exercise sets can also be seen from Figure 5 that depicts the submission counts by exercise set for individual students. By average, students have made less than 1.7 submissions for Derivation exercise set, while the respective average submission counts for Polynomial and Inequality exercise sets are 7.8 and 6.6.

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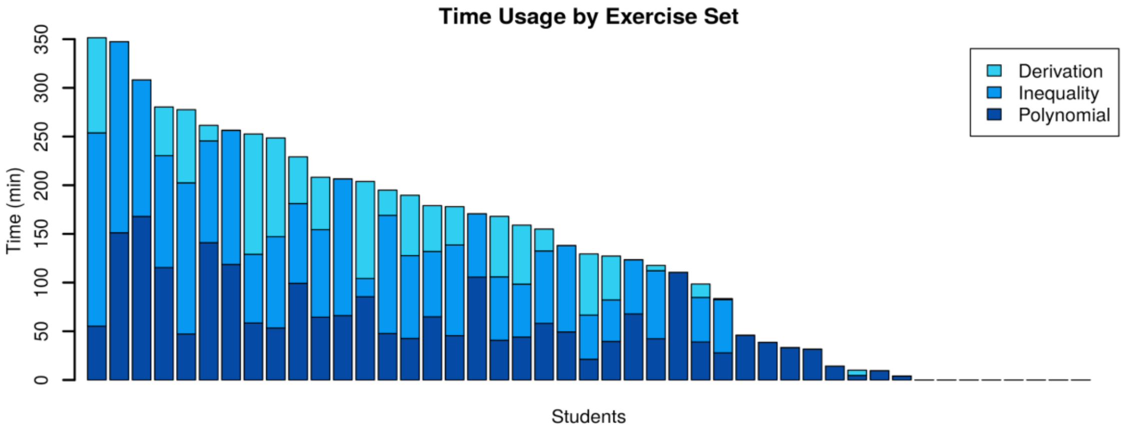

Figure 4. Students' time usage by exercise set throughout the course sorted from largest to smallest. Total time usage distributes almost uniformly among the students. Thresholding is not as clearly visible as it is for the submission scores. Also, most of the time is distributed between the first two exercise types.

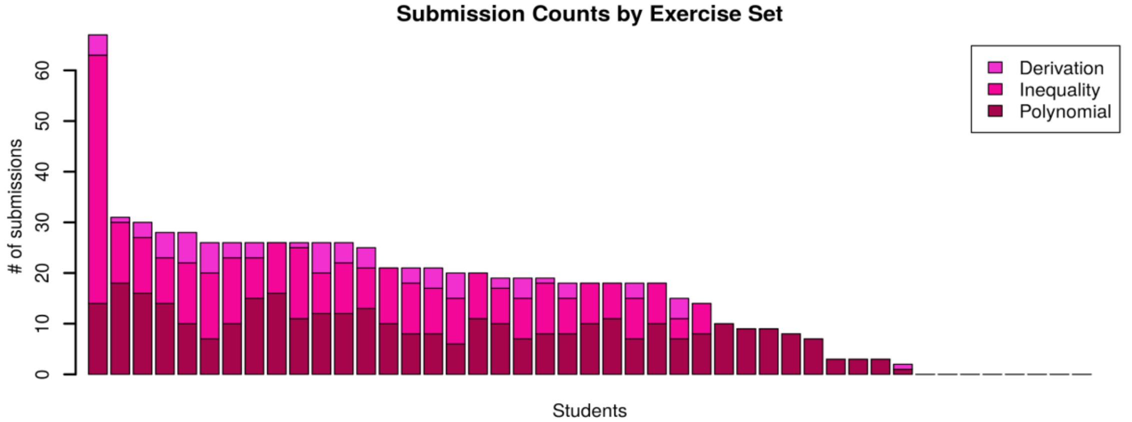

Figure 5. Sorted students' submission counts by exercise set throughout the course sorted from largest to smallest. The submission counts for the Derivation Rule Exercise Set are clearly less than those of Polynomial Equation Set or Inequality and Sign Chart Set. The student on the far left displays iterative behavior in the Inequality exercise set.

6. Conclusions and Future Work

Automatic assessment and immediate feedback motivate the students and increase the amount of work done without students easily realizing they are doing more work. Yet, at least older students are aware of the difficulty and relative reward of the work. It would be meaningful to test the effects of different relative weightings and thresholds for the exercises to achieve the optimal student performance levels for older students.

Case 1 shows, that even with good tools, the classroom setup must be taken into account. The tool must be used in a meaningful way. Other things to consider are: how to reward for the work done at school, how about at home? What is the sanction for undone work? As seen in case 2, these questions are mostlyrelevant for university level students as well. There must be something in it for the students too: the reward should be relative to the time spent doing the exercise.

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Can artificial intelligence help STEM students develop intelligence?

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Abstract

The word intelligence is widely used and has many meanings. In the educational context one talks of multiple intelligencies, including crystallized and fluid, the crystallized intelligence relying on the so-called declarative memory and the fluid intelligence, on procedural memory. The current approaches to STEM education are trying to shift from developing declarative memory to procedural and thus from developing their crystallized intelligence to development of fluid intelligence. We discuss these concepts in the context of mathematical education of engineers and give examples from our educational practice. We put a particular emphasis on the role of on-line resources and various interactive apps in developing students' intelligence. We discuss further why in our view, this task is important.

Keywords: *STEM students, mathematics teaching, procedural memory.*

1. Introduction

There is no concensus as to what constitutes intelligence. One theory that has had a certain influence on educational policy for many years now is Howard Gardner's idea of multiple intelligences [3]. He suggested that there are at least seven separate, relatively independent intelligences: linguistic, logical-mathematical, spatial, bodily kinaesthetic, intrapersonal, interpersonal, and musical. It is more advanced than the theory behind IQ testing, which relies on one type of intelligence only but both are based on various (consciously or unconsciously) accepted and rejected assumptions.

One definition of intelligence that could be used in education of STEM students, from an otherwise highly suspect public statement "Mainstream Science on Intelligence" (1994) issued by a group of academic researchers in fields associated with intelligence testing:

> A very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience. It is not merely book learning, a narrow academic skill, or test-taking smarts. Rather, it reflects a broader and deeper capability for comprehending our surroundings—"catching on," "making sense" of things, or "figuring out" what to do.

However, Gardner's definition [4] appears to be more helpful:

> A human intellectual competence must entail a set of skills of problem solving — enabling the individual to resolve genuine problems or difficulties that he or she encounters and, when appropriate, to create an effective product — and must also entail the potential for finding or creating problems — and thereby laying the groundwork for the acquisition of new knowledge

Both assert problem solving and learning ability as aspects of intelligence, and indeed it is hard to imagine anyone to be considered as possessing of intelligence if problem solving and learning are not their strong points! However, the first definition also emphasises speed of learning and ability to plan. It is true that many of those who are not involved in challenging intellectual pursuits believe these to be signs of intelligence, but many of those who do think otherwise. While it is true that in some circumstances speed of learning and good planning are of essence, the underlying and untested assumption used in the first definition is that this is always the case.

Digging a bit deeper, the educational literature distinguishes between two types of intelligence, crystallized and fluid. Crystallized intelligence is defined as something that is supposed to stem from learning and acculturation and that can be revealed in tests of knowledge, general information, vocabulary and a wide variety of acquired skills [1], while fluid abilities is something that is supposed to drive the individual's ability to think and act quickly, solve novel problems, and encode short-term memories. They have been described as the source of

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intelligence that an individual uses when he or she does not already know what to do. Fluid intelligence is grounded in physiological efficiency, and is thus relatively independent of education and acculturation [1], [6]. The definitions mention memory just in passing, even though one of the common assumptions is that memory and intelligence are almost two sides of the same coin. For example, people who are seen as being good at maths are often able to solve problems in their head, and the reason they can do this easily is because they can quickly retrieve stored information, which allows them to solve the problem successfully. They are not necessarily more “intelligent” overall but rather, they are able to store mathematical data in their long-term memory and retrieve it quickly when they need to. However, the two are linked and improving your memory can help you to display what is commonly seen as “intelligence”.

The common division of memory is into long-term (events and knowledge from our pasts) and short-term memory (recent knowledge and happenings). Another way to classify memories is into explicit memories, which are things you can recall consciously and which you can describe verbally and implicit memories, which are the skills and procedures which you learn, such as dancing or playing a certain sport or even driving. Memory is also sometimes specified as “working memory”, which is the ability to retain and manipulate information – for example, doing mathematics calculations in your head rather than using a pen and paper. Those who do not have good working memory are told by some that they can never learn maths and by others, that if they exercise their memory long enough they are bound to get better. Many approaches to teaching math are based on an elaborate system of memory tricks, the more entertaining the better the teacher is judged to be.

However, more and more researchers realise that the concept of intelligence is culturally determined. We start with a revealing story: An anthropologist, Joe Glick, while studying the Kpelle tribe asked adults to sort items into categories. Rather than producing taxonomic categories (e.g. "fruit" for apple), they sorted into functional groups (e.g. "eat" for apple). Such functional grouping is something only very young children in Western culture would usually do. Glick tried and failed, to teach them to categorize items. Eventually he decided they simply didn't have the mental ability to categorize in this way. Then, as a last resort, he asked them how a stupid person would do this task. At this point, without any hesitation, they sorted the items into taxonomic categories. "They could do it, but in their culture, it was of no practical value. It was stupid."[5]

Similarly, while some working memory is necessary its importance for doing mathematics is greatly exaggerated. It is hardly ever discussed in the psychological literature that professional mathematicians often perform very badly on the so-called numeracy tests or that, contrary to received wisdom, their crystallized intelligence decreases with years while the fluid one increases. The same applied to speed of calculations. While it used to be important for shop-keepers (and is not anymore even for them), it is of no value to most professionals using mathematics in the days of computers: Ability to connect mathematical and engineering or scientific concepts and come up with new ones – even if takes time – is of much greater value in most professional pursuits.

The main emphasis of this paper is on teaching mathematics to STEM students. It is well known that with the widening participation many freshers are ill prepared, have poor short-term and working memory, poor pattern recognition abilities, little time to study and little interest in learning math. The usual approach is to accommodate such students by reducing curriculum and developing memory tricks and tests to assist development of their short-term memory (superficial learning), so that they can memorise longer and longer sequences of symbols that make no sense to them.

We argue that a more constructive approach is to concentrate on developing their long-term memories (deep learning), in particular the memory known as procedural - a memory for the performance of particular types of skill-based actions. Most frequently it resides below the level of conscious awareness. When needed, procedural memories are automatically retrieved and utilized. One model for understanding skill acquisition was proposed by Fitts and his colleagues [2]. It maintained that learning was possible through the completion of three stages,

- Cognitive phase
- Associative phase
- Autonomous phase (also called the procedural phase)

The cognitive phase involves breaking down the desired skill into parts and understanding how these parts come together as a whole for the correct performance of the task. The associative phase involves individuals practicing the skill until patterns of responding emerge. At the autonomous phase discrimination between important and unimportant stimuli is performed faster and faster and less thought process is required because the skill has become automated. Most current approaches to teaching maths concentrate on the associative phase.

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Our experience showed that if the cognitive phase is performed properly the requirement for the associative phase is much reduced. Systems based on artificial intelligence can be used to perfect the cognitive phase.

The paper is organised as follows: In Section 1 we make a quick review of artificial intelligence in knowledge-based systems. In Section 2 we touch upon the use of artificial intelligence in knowledge management. In Section 3 we discuss use artificial intelligence in teaching of mathematics to STEM students. In Section 4 we demonstrate how artificial intelligence can be used to develop a productive cognitive phase when teaching STEM students graph transformations. Conclusions are presented in Section 5.

2. Artificial intelligence in knowledge-based systems

Five of the most common artificial intelligence tools include knowledge-based systems, fuzzy logic, inductive learning, neural networks and genetic algorithms. There is widespread use of these tools in engineering today due to their availability, power and affordability of computers. In addition to development of intelligence and improvement of learning, artificial intelligence has potential impacts on other aspects of engineering such as extraction of information and knowledge from large databases and multi-agent, distributed self-organising utilising autonomous entities operating concurrently in unpredictable environments with other entities and processes [7 - 12].

There are links between culture and the use of artificial intelligence, which must be explored, understood and exploited in order to fully utilize the positive aspects for improvement of learning. Culture is a way of life of a people or community. In constructing learning culture plays an important role, and both the teacher and learner have individual responsibility for learning. This is true whatever the mode of delivery, be it face-to-face (F2F) or via e-learning (blended or fully online).

The general purpose of AI has always been perceived to include the development of conceptual models, rewriting processes of these models and the programming strategies for the efficient reproduction as much as possible of most authentic, scientific and technical tasks of systems we classify as intelligent [13]. This is based on the assumption that we can synthesize these cognitive tasks, reduce natural language to formal language, semantics to syntax, neurophysiological symbols to static symbols, knowledge to architecture and processing information to calculus of mental or electronic circuits. Intelligent behaviour is that science that covers the set of facts linked with neurology and cognition from which functions of perception, memory, language, decision, emotion and action emerge. Three published works comprised what can be considered as the foundations of current AI paradigms. They include firstly the introduction of the formal neuron concept, which gave rise to the connectionist paradigm [14], secondly the introduction of the foundations of the symbolic paradigm when human knowledge was interpreted in terms of declarative and modular descriptions of high level symbolic entities as well as inferential rules used to handle the symbolic descriptions [15] and thirdly the introduction of the bases of situated paradigm when intelligent behaviour was interpreted in terms of a set of feedback mechanisms [16]. The implications of these are that AI transforms technology by allowing traditional things to be done in a dramatically different way. Often AI lead to cheaper, faster and better solutions. AI applications are seen to be developing in an evolutionary manner, which is transforming a wide range of human activities including learning.

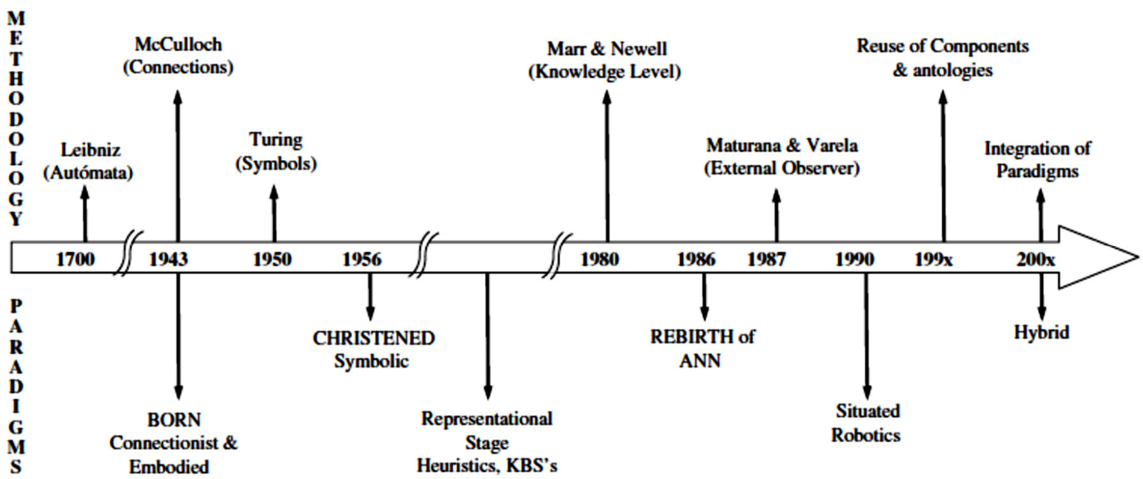

Figure 1. Historical development of AI showing methodological steps and paradigms (lower) after ref. [17]

Different models have been proposed for AI. The historical development of artificial intelligence has seen a progression from Leibniz's automata in the sixteenth century through Turing's use of symbols and Maturana and Varcla's external observer methods to the present days attempt at integration of paradigms.

3. Artificial intelligence in knowledge management

In this era of globalization, which places emphasis on knowledge economy, its development and the building of knowledge organizations, it has become apparent that knowledge management will play an important role in the process of successfully transforming individual knowledge into organizational knowledge. Artificial intelligence is a key building block for the development and advancement of knowledge management, which is the process of creating value from intangible assets [19 - 21]. Knowledge management deals with leveraging knowledge and combines various disciplines, such as artificial intelligence, information technology, human resources etc., with a focus on how best to share knowledge. It is important to distinguish between information and knowledge. Whilst information is patterned data, knowledge comprises the set of facts and rules of thumb that experts may have acquired over many years of experience and hence is the capability to act. Knowledge takes various forms and could be either tacit or explicit. Tacit knowledge is knowledge of the subconscious. It is something done automatically, almost without thinking and due to the engineering paradox, this type of knowledge is difficult to extract and elicit. The other form of knowledge is the explicit type, which is more obvious and is easy to document. Internalized knowledge is how explicit knowledge is shaped or influenced by one's own views and is differs from one individual to another. Through the documented form of knowledge insight could be gained into how current artificial intelligence is affecting and shaping culture for improved management of knowledge and practice.

4. Artificial intelligence in teaching mathematics

From the time of early mathematicians like Pythagoras we have seen efforts to solve mathematics problems using different tools, techniques and approaches. In the past two centuries we progressed from slide rules to calculators to computer packages, such as Mathematica. It is time to move on to the intelligent tutoring systems.

Compared to traditional systems, it has been argued that the use of intelligent tutoring systems with computer based training, multimedia and hypermedia enabled leads to higher learning gains and improved learning, especially of mathematics [22 - 25]. This sparked the development of some commercial technologies that target mathematics such as MyMathLab [26] and cognitive tutors at Carnegie Learning [27, 28]. Research work done using ALEKS (Assessment and LEarning in Knowledge Spaces), an Intelligent Tutoring System for mathematics is well documented [29, 30]. It is a web based learning system with AI (artificial intelligence) components. The artificial intelligence of ALEKS is based on a theoretical framework known as knowledge space theory (KST, see http://wundt.uni-graz.at/kst.php), which allows for precise description of what the student knows, does not know and is ready to learn next. The student knowledge state is then correctly known and described. ALEKS has an assessment engine, which attempts to uncover the knowledge state of a particular learner using efficient questioning. This has been used to study and gain some level of understanding on how artificial intelligence impacts on students' knowledge and implications for performance and impacts on learning.

The learning styles of students could provide useful indication of the level of readiness to engage with study and the ability to fully utilize technology to improve learning and should be taken into account when developing cognitive tutors. Amongst the recognized styles of learning the visual learners are the ones who are able to visualize data to retrieve useful information using diagrams, graphs or other appropriate means, the knowledge and skills that they have acquired and have them applied or represented in a form recognizable by another. The use of graphs to show association and relationships has remained an important aspect used to establish this deep understanding. The availability of technology has helped to improve and simplify this process.

In order to fully gauge the effect of learning styles on individual's intelligence it is important to be able to relate the learner's perception, processing, understanding and use of what has been learned. This is by no means an easy or simple task and shall form the basis for our next paper. Learning styles are useful indicators and characterize the cognitive, affective and psychological behavior of learners, which serve as relatively stable and useful indicators of how learners perceive, interact and respond to the learning environment [18].

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5. An example: proposed use of AI in constructing a cognitive phase for teaching STEM students graph transformation

The topic of graph transformation considered in this example should be introduced after the students mastered the order of operations, concepts of the function and function graphs and learned to sketch the functions using the table. The cognitive approach requires that they also master the basic mathematical terminology, in particular, words like term (sometimes called and addend) and factor (sometimes called a multiplier). Then the cognitive phase should revolve around the careful explanation that if they know how to sketch a function $y = f(x)$, any composite function, which involves the rule f and addition of a constant to an independent variable x or dependent variable y, or else multiplication by a constant of an independent variable x or dependent variable y, then such composite functions can be sketched using simple transformations (translation, scaling or reflection) of the curve $y = f(x)$. It is described in [31]. The associative phase can be carried out using the Decision Tree presented in Figure 2.

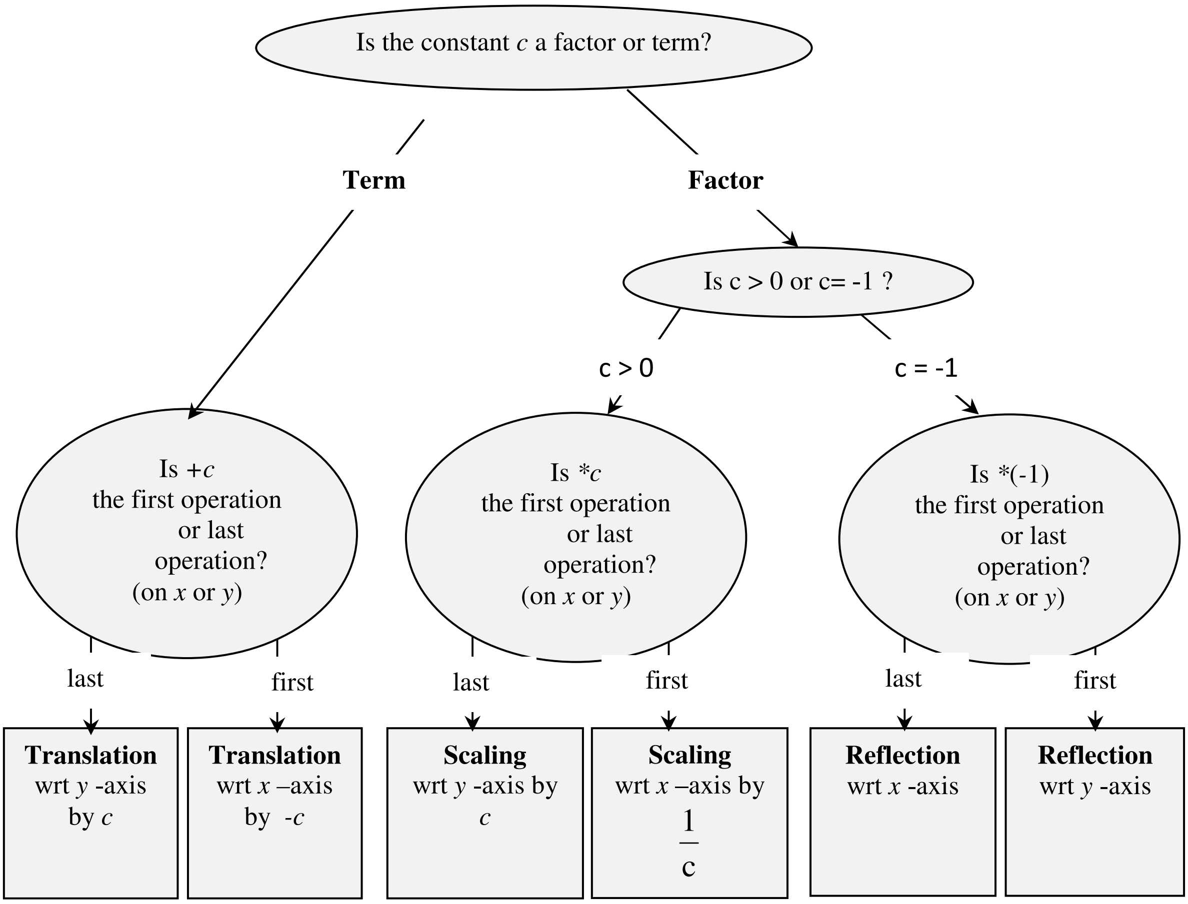

Figure 2. The Decision tree for sketching by simple transformations.

The decision tree like this should be supplied with a note that if c affects neither the first operation nor last, it is not applicable. The students should try algebraic manipulations first in order to present the function in one of the forms it covers. Since the tree is based on an algorithmic approach it can be coded to create a cognitive tutor, an expert system of the type described in [32] to take the students through the associative phase, helping them to achieve the autonomous phase at record times. The paper also describes students' reaction to the prototype cognitive tutor of this type, developed by the first author. The full app remains the task for the future.

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7. Conclusion

We conclude that artificial intelligence has the potential to contribute to the cognitive phase in students' learning, developing their fluid intelligence, enhancing their understanding of concepts and ability to apply knowledge and skills. The grasp of basic concepts leads to positive learning experience of STEM subjects in general. The availability, spread and use of technology has already led to adoption of novel teaching and learning schemes and approaches, especially in engineering and mathematics. Concentrating on developing new tools of the kind proposed in this paper for speeding up the cognitive phase, informed by best practice could bring a qualitative improvement in delivery of learning. Issues of culture and individual responsibility of the learner are important and must be addressed if the potential of these tools is to be realised.

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Modeling, Simulations and Optimization

ICEE 2015

Enhancing Engineering Education by exceeding simple simulations using Analog™ Discovery

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Abstract

Teaching and learning in engineering has developed remarkably over the past few years with the advent of educational technologies where more course material has been conveyed to students in a more effective and efficient way. However, challenges regarding improving throughput rates, enhancing student understanding of theory and selecting best practices still remain at Universities of Technology where a large part of the course material is taught in laboratories. The purpose of this paper is to introduce an approach which was adopted in a Control Systems Laboratory that not only improves student understanding of theory, but also increases the time-on-task which students spend on practical assignments. This is accomplished by the use simulations in MATLAB® where the results are verified by students using practical hardware equipment in the form of the Analog™ Discovery equipment. Advantages of using this approach in contrast to using only laboratory simulations includes student satisfaction, increased time-on-task and improved cognitive skills.

Keywords: *Control, MATLAB®, Simulink, Analog™ Discovery, clicker.*

1. Introduction

Teachings in engineering are becoming more challenging as the need to cover more topics in the curriculum from basics to detail in the same period as traditional education thereof [1]. Basic concepts need to be mastered by the student but the vast amount of new technologies needs to be covered as well.

This is mainly achieved by lecturing the main concepts and leaving the leaner to obtain the rest by facilitation and self learning [2]. This puts additional strain on the student in terms of time management and financial burdens implemented by this teaching paradigm.

Implementing simulations and practical teaching stays a good practice as evident at Universities of Technology. The laboratory equipment is expensive for students, though necessary, to obtain for themselves and thus changing their own learning strategies [3].

Thus the purpose of the article is to look at the problems involved in these teachings and some solutions to obtain a possible better result not sacrificing standards and quality. Control Systems is taken as the test subject utilizing MATLAB® simulations and implementing the practical part of the study material on an AnalogTM Discovery rather than using expensive lab equipment, like an oscilloscope, function generator and power supply.

The article firstly considers how the subject Control Systems is taught, then taking an example from the curriculum to compare the old and new teaching methods. A financial comparison between the two methods then follows along with the implementation of the new method. Student feedback on using the new method is then presented along with succinct conclusions.

2. Teaching and facilitation with Control Systems

The current teaching and facilitation in the subject Control Systems 3 at the Central University of Technology, Free State entails the covering of the syllabus by means of teaching the material in a time frame of four by forty minute theory periods. The facilitation and additional teaching is done in a laboratory for three by forty minutes periods. The particular theory covered is accentuated by using simulations on MATLAB® and/or Simulink together with a practical setup of the theory work to be evaluated and commented on by the student's participation and documentation [4].

The evaluation consists of two tests and a final examination on the work including the individual's findings in the report derived from the laboratory teachings as a summative teaching style [5]. Theory classes are conducted

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as a large class teaching and facilitation by means of lectures where practical's are implemented dividing the student groups into smaller groups attending the laboratory [6].

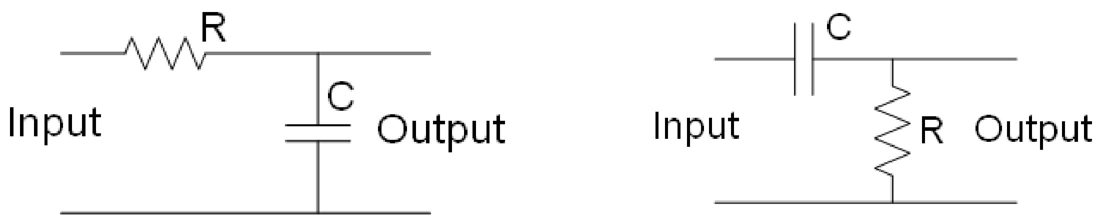
3. Using examples from the curriculum

This section illustrates the first order integrator and differentiator action in Control Systems as an example to explain the different adaptations in the practical teaching method introduced as the normal teaching and facilitation versus the facilitation with the Analog™ Discovery method.

3.1. Current teaching method used in Control Systems

Step1:
The integrator and differentiator action are explained as a large class theory section introducing the model as a possible low- or high pass filter in electronics [7]. This concept is used to teach the students the modeling of systems in the frequency domain.

Figure 1 shows a typical first order low- and high pass filter circuit respectfully to be used, with the values for R = 22kΩ and C = 10µF.



(a) **(b)**
Figure 1. (a) 1st order low pass filter circuit. (b) 1st order high pass filter circuit.

Step2:
After the student encountered the theory on the topic, he/she then attends a laboratory session where simulations on the topic are done in MATLAB® and/or Simulink to encourage further learning and understanding [3].

To be able to simulate the circuit in MATLAB® the circuit needs to be written as a mathematical equation. Equation 1 represents only one of the necessary equations for demonstrating purposes representing the input to the low pass filter seen in Figure 1(a).

$$Input(t) = Ri(t) + \frac{1}{C}\int_0^t i\,dt \tag{1}$$

The equations need to be transformed to the *Laplace* domain and written as a transfer function representing the Output/Input, as can be seen in equation 2 - representing the low pass filter.

$$\frac{Output}{Input} = \frac{1}{1 + RCs} \tag{2}$$

MATLAB® simulation:
For a simple *step response* simulation the circuit written in *Laplace* format needs to be entered as a transfer function in MATLAB® [8].

The following code is entered in the command line of MATLAB® [9], with the result shown in Figure 2;

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```
>> R=22000;
>> C=0.00001;
>> num=1;
>> dem=[R*C 1];
>> LP=tf(num, dem)

LP =

      1
  ----------
  0.22 s + 1

Continuous-time transfer function.

>> step(LP)
```

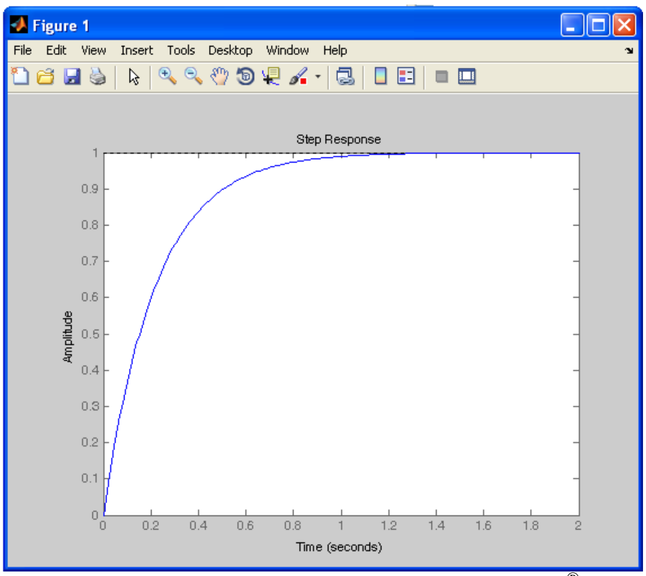

Figure 2. Result of low pass filter in MATLAB®.

Simulink simulation;
The following model is created for the same low pass filter in Simulink, with the result shown in Figure 3;

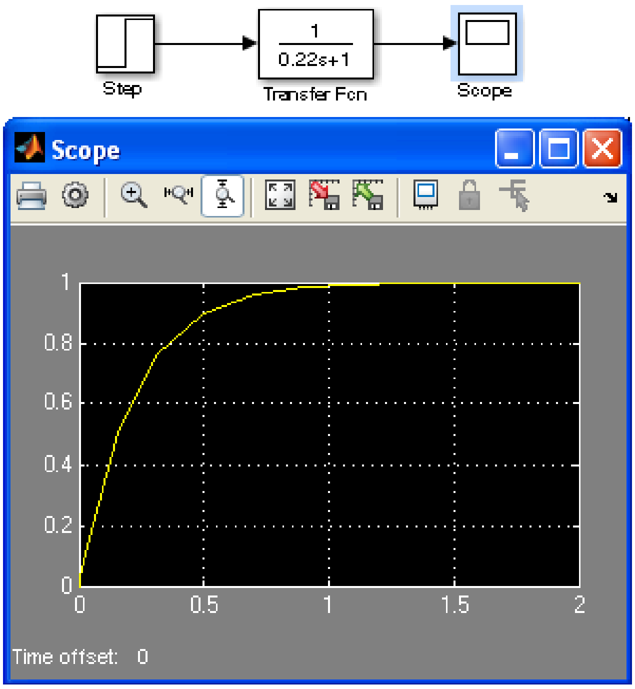

Figure 3. Result of low pass filter in Simulink.

Step3:
Only then the students start to build the circuit and do the expected evaluations with the test equipment and report on their findings. The report is then assessed by the assessor appointed. A typical setup with the equipment relevant to such an experiment is shown in Figure 4, with a function generator and dual trace oscilloscope with a circuit built on breadboard.

Doing an experiment including active filters a power supply is also needed for the supply voltage of the operational amplifiers.

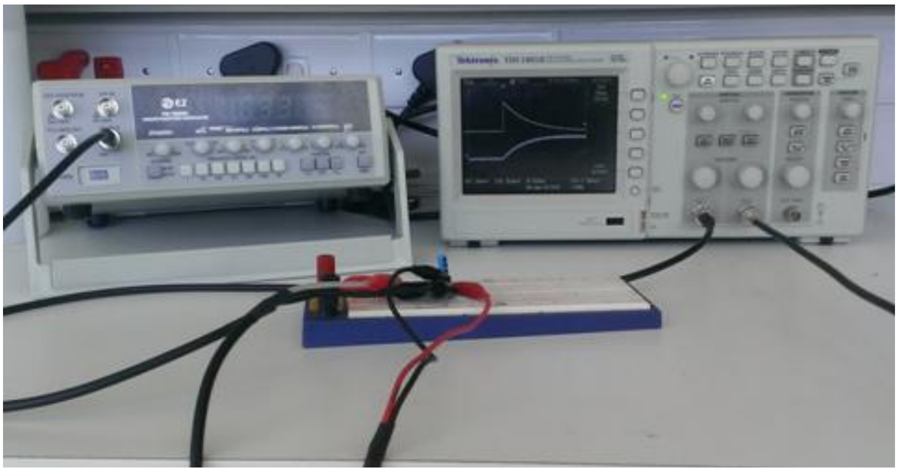

Figure 4. Setup for a practical experiment using an oscilloscope, function generator and circuit.

3.2. Proposed teaching method for Control Systems

In this proposed method steps 1 and 2 of the current teaching method stays the same and still needs to be executed. Step 3 is replaced by this proposed method or done in conjunction with step 3 of the current teaching method for evaluation purposes in a practical class.

In step 3 is where the Analog™ Discovery portable analog circuit design kit is to be used [10]. In summary it consists of:

- Dual Channel Oscilloscope,
- Function Generators,
- 16 Channel Logic Analyzer,
- Dual Power Supplies and
- Universal Serial Bus (USB) Powered.

Figure 5 shows a typical setup for the experiment in steps 1 and 2 and instead of utilizing a function generator and dual trace oscilloscope in conjunction with the breadboard the Analog™ Discovery is used [11].

Figure 5. Picture of a typical practical setup for an experiment

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A step function is generated by the Analog^{TM} Discovery *function generator* (see Figure 6) and used as an input to the circuit (shown in Figure 1 (a)) on breadboard. The input and output could then be monitored by the Analog^{TM} Discovery *dual channel oscilloscope* (see the Signal extraction compared to simulation
Figure 7). This makes the use of the function generator and oscilloscope obsolete by using the Analog^{TM} Discovery.

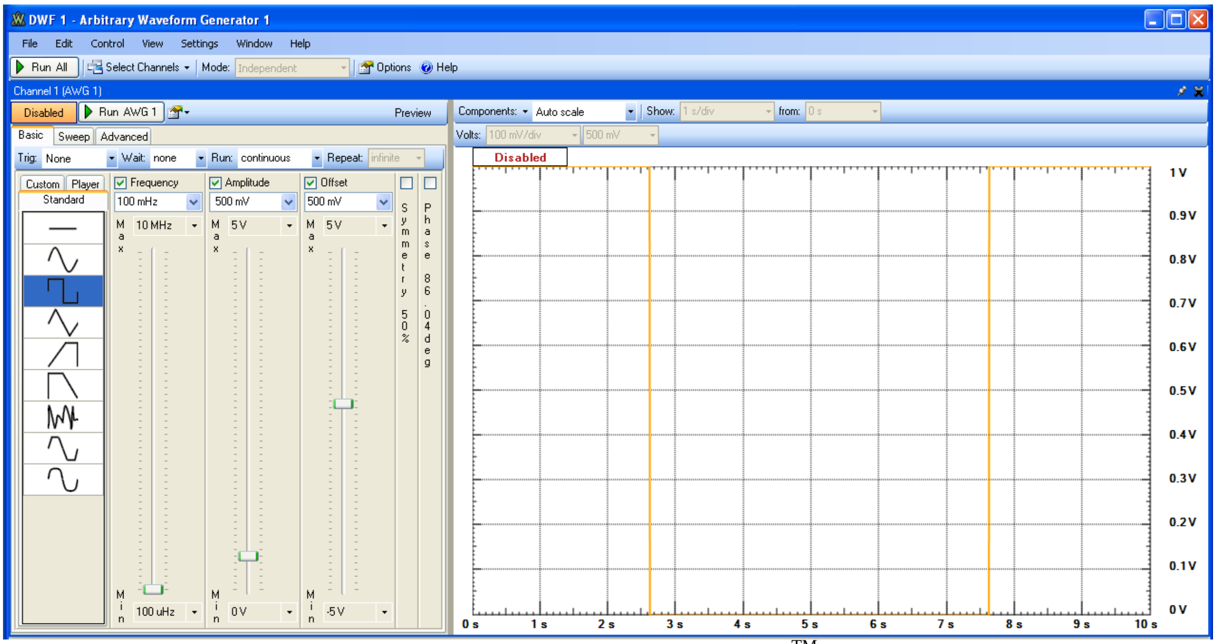
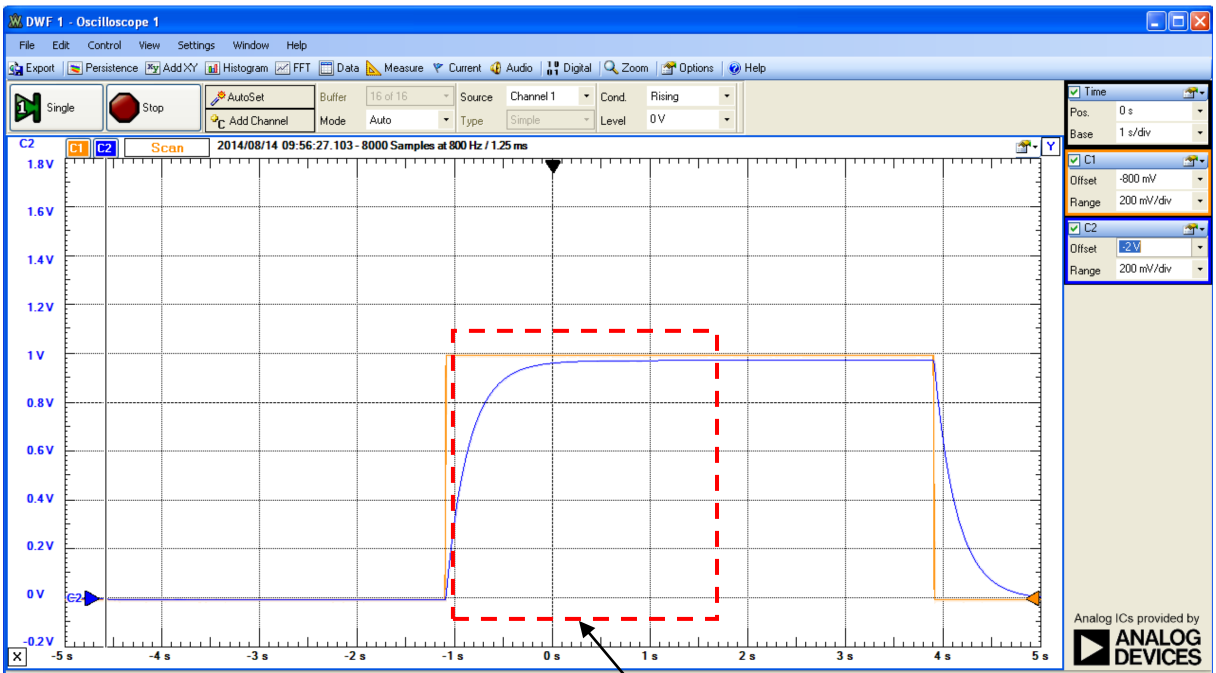


Figure 6. Generated step function by the Analog^{TM} Discovery

Figure 6 represents a square wave function rather than a step function. This was done on purpose as the laboratory equipment can only generate a square wave function and by tracing a step function a storage oscilloscope would have being needed. The Analog^{TM} Discovery however can generate any requested waveform like a step function.



Signal extraction compared to simulation

Figure 7. Input and output response monitored by the Analog^{TM} Discovery

Figure 7 indicates the dual trace of the input compared to the output signal which correlates to the result expected seen from the simulations in MATLAB®, Figures 2 and 3.

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Additional to these results, as the Analog™ Discovery is supported by MATLAB® version R2013a onwards, it is possible to access the device through MATLAB® code [11]. Figure 8 shows a code extraction of such an example reading a signal source on an analogue input and displaying the plot thereof.

```
%% Create session with Digilent Analog Discovery, add analog input channel
s = daq.createSession('digilent');
ch = s.addAnalogInputChannel('ad1', 1, 'Voltage');
%% Set sampling rate and range
s.Rate = 300e3; % 300 KHz sampling rate for Analog Discovery hardware
s.Channels.Range = [-2.5 2.5]; % set Range
%% Collect 0.1 seconds of data
s.DurationInSeconds=0.1;
[data, timestamps] = s.startForeground;
%% Plot data
% 10 kHz external test signal with +-500 mV amplitude is connected to the
% channel 1+ and 1- oscilloscope input pins of Analog Discovery hardware
plot(timestamps, data);
axis([0.03 0.035 -0.6 0.6]);  % zoom in to show signal
xlabel('Time (seconds)'); ylabel('Voltage (Volts)');
```

Figure 8. Example of accessing the Analog™ Discovery with MATLAB® code

4. Comparison between the current and proposed methods of teaching

By comparing the two methods, the assumption is made that the student does have a personal computer (PC) or laptop of which steps 1 and 2 was completed on.

Table 1 indicates the different costs to the student or teaching institute for the equipment used and necessary for each teaching method for this specific experiment.

Table 1. Cost comparison between the current and proposed method of teaching

	Cost for current method	Cost for proposed method
Multiple Output Linear D.C. Power Supply	R2306,88	
Function Generator	R4183,52	
Dual Trace oscilloscope	R6251,01	
Analog™ Discovery		R3536.25
Total cost	R12741,41	R3536.25
	\$1032,05*	\$286,44*

* Rand dollar exchange rate on 2015-03-11 R1 = \$0,081 US

This table clearly indicates the large cost difference between the two methods, excluding any possible academic discounts which may be awarded for both cases. This suggests that the new method is a more viable option for both students and faculty alike, as it represents a considerable financial savings as compared to the old teaching method. This new teaching method has the added potential of being portable, thereby extending the time-on-task which students spend on their practical assignments.

5. Initial implementation of the Analog™ Discovery

Thirty of the Analog™ Discoveries were budgeted for and then bought by the Department of Electric, Electronic and Computer Engineering as is was still very expensive to be bought by the students themselves.

The lectures, as explained in section 3, were conducted and the students were then introduced to the Analog™ Discovery by means of a demonstration. They then conducted a first experiment and their responses were then evaluated by means of a questionnaire using an electronic response system [12].

Although the class were larger a sample of 25 students were taken representing the class. The questions and results are depicted in Table 2.

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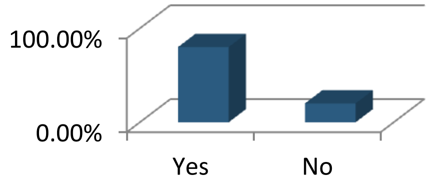
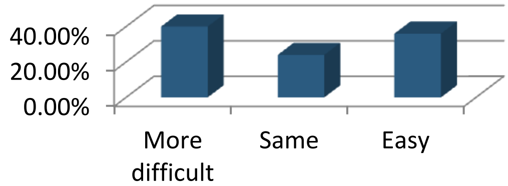
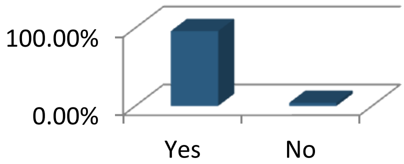
Although positive results were expected from the questions not all proved to be, as questions 2, 4 and 5 indicates.

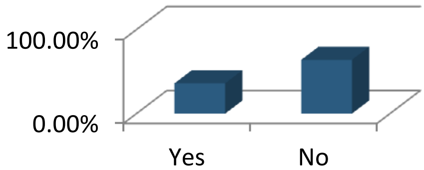
Table 2. Questionnaire and results obtained from a sample of the control class practical

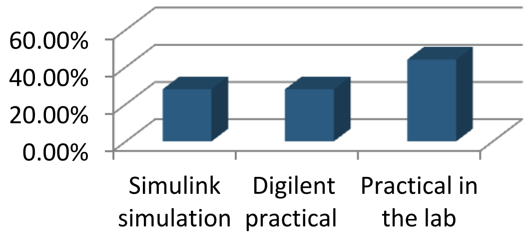
<table>
<tr><th>Question to the sample representing the class</th><th>Replied result</th></tr>
<tr><td>1. Would you think of buying such a device for R2408.52?

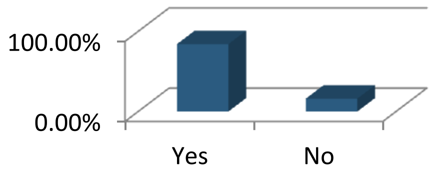
✓ expected</td><td>
</td></tr>
<tr><td>2. How did you find using the Analog™ Discovery device compared to the normal lab equipment?

✗ not expected</td><td>
</td></tr>
<tr><td>3. Would you engage more into doing Control experiments, if you have such a device?

✓ expected</td><td>
</td></tr>
<tr><td>4. Did you learn and understood the experiment better after using the Analog™ Discovery device?

✗ not expected</td><td>
</td></tr>
<tr><td>5. Which practical taught you more about the experiment?

✗ not expected</td><td>
</td></tr>
<tr><td>6. Would you like to do more experiments on the Analog™ Discovery device even in practical classes?

✓ expected</td><td>
</td></tr>
</table>

The reason to question 2's result could be the inexperience of the class with the Analog™ Discovery compared to laboratory classes to which they are familiar with, although the larger part of the class felt it was easy or similar.

The result to question 4 was unexpected but the assumption is that the experiments that the students do are well prepared for and more used to by the students and the Analog™ Discovery still new and unknown. A positive result though for the practical class.

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Again question 5 favors that to which the students are used to but do show promise by utilizing the Analog™ Discovery.

6. Conclusions

The experiment could be conducted equal successfully by both methods but with the added advantage to the student that the Analog™ Discovery is much smaller and portable than the other equipment used in the laboratory. The portability of the Analog™ Discovery makes it possible to do their work at any venue, even off campus. This portability also adds to the strategy of extending the student's learning time of the subject material covered and self learning ability.

It would also make sense financially to implement the Analog™ Discovery, but as a University of Technology the use of standard equipment used in industry is to the student's advantage. Thus incorporating both methods are a positive.

Looking at the advantage of the fact that the Analog™ Discovery is supported by MATLAB® further self learning is or could be propagated by the possibility that the student could write their own graphical users interface (GUI).

The student can add extra time for self learning, add to their knowledge by spending time with or use the device and gain valuable extra knowledge in even other related subjects as well.

7. Acknowledgments

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Modeling, Simulations and Optimization Based on Algebraic Formalization of the System

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Abstract

The problem of improving algorithms, forecasting accuracy and quality planning system functioning, as well as evaluation of the effectiveness of its functioning, is one of the most difficult and important problems in many spheres of human activities, especially in the field of economics and finance, expert systems in General Theory of Education.
The need for new mathematical methods is due to disadvantages of mathematical methods currently used for forecasting and planning in different closed systems such as financial and economic systems, system knowledge representation in an intelligent computer-aided training and control system and so on.
The goal of this paper is to present new methodology of mathematical modeling allows one to get meaningful results in various fields of activity using the system approach and closed systems such as the modeling of economic phenomena and processes, expert systems in the General theory of education and to obtain a single complex of qualitative and quantitative indicators describing the studied process or phenomenon.
The proposed in this paper methodology is based on the formalization of General Systems Theory using the methods of General Algebra and, in particular, the Theory of Algebraic Systems, Model Theory and Group Theory.

Keywords: *Modeling, System, Algebraic Formalization.*

1. Introduction

Main disadvantages of mathematical methods currently used for forecasting and planning in different closed systems such as financial and economic systems, system knowledge representation in an intelligent computer-aided training and control system and so on are:
Econometric methods:
- the impossibility of application of the apparatus regression in crisis periods, as the accuracy of forecasts is not provided. Econometric models are not suitable for forecasting turning points of the system.

Methods of expert evaluation:
- the inability to build a holistic model for the problem to be solved, structure and causality model is not identified;
- the inability to predict converging ways of development and changes in competitive systems;
- the vagueness of the judgment to reduce liability.

The proposed in the present paper methodology of mathematical modeling, based on algebraically formalization of the system approach is an alternative to the currently used and allows in contrast to previously used to characterize the studied properties in a single integrated complex as numerical indicators and synchronized with them relationships, in dynamics, using dynamic predicates, the theory of which is being developed at the present time, and in statics, using static predicates, the theory of which was built by A. I. Maltsev, [2]. For the General theory of systems dynamics systems may be reflected by the complexity of relationships, gradually emerging in the process of functioning of the system. For economic systems dynamics may be reflected by the difficulty of levels gradually emerging relations in the economic system. For expert systems in the General theory of learning dynamics may be reflected by the difficulty levels of the tests, controlling the learning process.

The development of mathematical modeling has shown that Group Theory can be used not only in its nearest areas. A.G. Kurosh, [3], believed that Group Theory with the necessity will have an increasingly significant impact on various fields of science including outside of mathematics. This statement applies not only to the mathematical field, but to scientific research in general, because the notion of a group is well formalized, reflects a fundamental property of things - symmetry and therefore is associated with notions of appropriateness, proportionality, optimality. Application of group theory, for example, in physics, is possible because the theory of groups is well formalized and allows one to explore the invariance principle, according to which physical law with the need is invariant in any inertial system and, therefore, retains its shape under all transformations of four-dimensional space-time transforms the inertial system into inertial ones. The group of all transformations under which Maxwell's equations for electromagnetic fields remain invariant, described by H. A. Lorentz, led to the formation of the special theory of relativity. In the present article we propose to develop applications of the Theory of Algebraic Systems, Model Theory and Group Theory to formalize General Systems Theory and after that to show how the proposed formalization may be used to obtain and prove the meaningful results in General Systems Theory, and then, as a consequence, the meaningful results in the modeling of economic phenomena and processes, and in the field of expert systems in the General theory of education. In 1992 – 1993 on the basis of studies Y.L. Ershov's scientific papers a way of highlighting and examination purities or net embeddings in a special class of algebraic systems group – in groups, which has allowed to transfer and generalize the known results of the theory of purities of abelian groups to the case of arbitrary non-abelian groups, was offered, [4]. In the 2000s, it has been developed a method of modeling final states of a system and the determination of the number of final states of a system has been developed with the use of the technique of group theory, [5]. In 2008 - 2014 pure embeddings within the meaning not to distort the internal relations of the system, satisfying the condition (predicate) *P*, have been used to distinguish connections in the systems due to their nature, i.e. to classify relations in general closed systems.

2. Main Results

The following theoretical results have been received in the field of systems theory with using algebraic formalization of a system:
- a new methodology for the study of systems theory based on the idea of formalizing a notion of a system approach using algebraic systems and methods of General algebra, which allows feedback between formalization and qualitative analysis to clarify the previously known concepts in the deepening of the study of qualitative properties;
- the axiomatic of a system is built under the proposed formalization, [8];
- the notions of a static predicate and a dynamic predicate are considered, [8];
- the proposed approach allows us to determine the equilibrium point of the system, as well as stable and not sustainable systems, [8];
- external and internal attributes of the system are described, [8];
- the property of integrity of a system is formalized, [8];
- the algorithm of study of a closed system using Group Theory is built, [6,8];
- the number of possible synergic effects of a closed system is defined;
- examples describing step by step operation of the closed system are built and, in particular, the simplest models describing the functioning of the tax system are built, [5];
- the notions of innovative system and its infrastructure are formalized and their properties are studied, [8];
- the concept of pseudo - innovation system is introduced and some comparative properties of the innovation and pseudo - innovative systems are studied.

The proposed approach allows to formalize qualitative changes in a closed system and thus to predict their ability.

3. Basic Definitions and Examples of *P* – purities in the class of All Groups

Here are the necessary definitions from [6,8].

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Definition 1. Under the algebra of factors of a system will be understood algebra $\bar{A} = \langle A | \{f_\alpha^{n_\alpha} | \alpha \in \Gamma\} \rangle$ with the fundamental set of factors A and the set of operations $\{f_\alpha^{n_\alpha} | \alpha \in \Gamma\}$ describing the interaction of the factors.

Definition 2. Subalgebra $\bar{B} = \langle B | \{f_\alpha^{n_\alpha} | \alpha \in \Gamma\} \rangle$ of an algebra $\bar{A} = \langle A | \{f_\alpha^{n_\alpha} | \alpha \in \Gamma\} \rangle$ is called P - pure (P - clean) in $\bar{A}$ if every homomorphism $\bar{B} \xrightarrow{\varphi} \bar{C}$ of the subalgebra $\bar{B}$ into $\bar{C}$, where $\bar{C}$ is an algebra of the signature $\{f_\alpha^{n_\alpha} | \alpha \in \Gamma\}$ of the of $\bar{A}$ and $P(\bar{C})$ is true and P is a predicate on the class of algebras of the signature $\{f_\alpha^{n_\alpha} | \alpha \in \Gamma\}$ closed under taking subalgebras and factoralgebras, can be continued to a homomorphism $\bar{A} = \langle A | \{f_\alpha^{n_\alpha} | \alpha \in \Gamma\} \rangle$ into $\bar{C} = \langle C | \{f_\alpha^{n_\alpha} | \alpha \in \Gamma\} \rangle$ i.e. the following diagram is commutative:

$$\begin{tikzcd} 0 \arrow[r] & \bar{B} = \langle B | \{f_\alpha^{n_\alpha} | \alpha \in \Gamma\} \rangle \arrow[r, "\alpha"] \arrow[dr, "\varphi"'] & \bar{A} = \langle A | \{f_\alpha^{n_\alpha} | \alpha \in \Gamma\} \rangle \arrow[d, dashed, "\beta"] \\ & & \bar{C} = \langle C | \{f_\alpha^{n_\alpha} | \alpha \in \Gamma\} \rangle \end{tikzcd} \tag{1}$$

that is $\beta\alpha = \varphi$.

Purity is, in fact, a fractal (self-similarity) relation. On the other, purity determines the quality of links, in our case - the quality of links with respect to the condition P.

The most studied case is if one considers P – purities in the class of all groups. The meaning of P – purities and examples of P – purities in the class of all groups run as follows. Chart (1) has the following meaning in the class of groups: epimorphic images of B and A in the class of all finite groups are one and the same. For P –purities the meaning runs as follows: B and A have the same epimorphic images in the class of all groups satisfying the condition P.

Examples of P – purities in the class of all groups:

- P allocates the class of all finite groups in the class of all Abelian groups, one get the usual purity in the class of all Abelian groups;
- P allocates the class of all Abelian groups in the class of all groups;
- P allocates the class of all finite groups in the class of all groups;
- P highlights the diversity in the class of all groups i.e. the class of groups closed under subgroups, homomorphic images and Cartesian products, such as Burnside's variety of all groups of the exponent (indicator) n defined by the identity $x^n = 1$, the variety of nilpotent groups of class of nilpotent is not more than n, soluble groups of length not exceeding the number l , etc.

One should to distinguish the notion of an algebraic system and the notion of a system in the proposed formalization. The notion of a system in the proposed formalization runs as follows, [6].

Definition 3.

By the system we should understand a two- dimensional vector

$S = \langle \{\langle S_\alpha, Q_\alpha, U_\alpha \rangle | \alpha \in \mathrm{A}\}, I(S) = \langle \{a_\beta | \beta \epsilon B\} | \Omega_S = \{f_\gamma^{n_\gamma} | \gamma \epsilon \Gamma\} \rangle \rangle$,

where $\{S_\alpha | \alpha \epsilon A\}$ is the set of all system S statuses which are possible as a result of a system S functioning, $\{Q_\alpha | \alpha \epsilon A\}$ is the set of all statuses of a system Q upon which system S affects, $\{U_\alpha | \alpha \epsilon A\}$ is the set of all statuses of an external environment which are possible as a result of system S functioning, $\{a_\beta | \beta \epsilon B\}$ is the set of all inner factors acting on system S that is determining its behavior, if the composition of factors $a_1 \circ a_2 \circ \dots \circ a_{n_\gamma} = a$, than let $f_\gamma^{n_\gamma}(a_1, a_2, \dots, a_{n_\gamma}) = a$ where $\{f_\gamma^{n_\gamma} | \gamma \epsilon \Gamma\}$ is a set of operations on the set of factors $\{a_\beta | \beta \epsilon B\}$, $f_\gamma^{n_\gamma}$ is n_γ -argument operation, $I(S) = \langle \{a_\beta | \beta \epsilon B\} | \Omega_S = \{f_\gamma^{n_\gamma} | \gamma \epsilon \Gamma\} \rangle$ is an algebraic system of inner factors of a system S. Let $\{P_i | i \in I\}$ be a set of all properties of a system S which it holds as a result of its functioning, $\{B_j | j \in J\}$ – is a set of all subsystems of a system S, $\{v_m^n | m \in M, n \in N\}$ is a set of all connections of a system S, $*$ is the operation of composition, $G(S)$ is a goal of a system S.

So we possess an algebra $< \{P_i | i \in I\} \ | * >$ in conjunction that the set of all properties of a system S is closed under composition * that is that we have full description of a system S.

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4. Formalization of Axiomatic Description of the Purposes and the Principles of a System

In [6] we proposed the following description of the set of axioms on the base of an algebraic formalization of a system.

4.1. Axiomatic description of a System

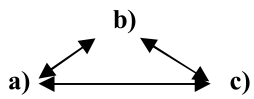
The proposed approach allows us to construct axiomatic description of a system, [8]. It runs as follows. At first let's consider the formalization of a system'spurposes. The system's purposes can runs as follows:

1. New status S_α of a system S,
2. New status Q_α of a system Q, on which system S affects.
3. New status U_α as a result of an external agency of a system S upon outdoor environment$U$, $\alpha \in \mathrm{A}$.

So, we have the target vectors $\langle S_\alpha, Q_\alpha, U_\alpha \rangle, \alpha \in \mathrm{A}$, and a final status S_f of a system S, corresponding to the vector $\langle S_f, Q_f, U_f \rangle$, in which the system S moved as a result of it's functioning. The following cases are possible:

a) 2 ⇒ 3, b) 3 ⇒ 2, c) 3 ⇒ 1, d) 1⇒ 3.

The graph $G(S)$ the impact of targets of a system S upon the environment U runs as follows:



Now based on the introduced notations and concepts one can go to the formalization of an axiomatic description of the purposes and principles of the system approach. Generally adopted axiomatic (even verbal one) of the system approach or of the theory of systems does not exist. Usually the following main principles are chose while describing the system: the presence of a target (set of targets), integrity (wholeness), hierarchy, good structure. Basic system's principles are opened in the following way. Integrity means fundamental irreducibility properties back to the sum of the properties of its constituent elements and revivalist of the last properties of the whole, the dependence of each element, properties and relationships of the system from his place, functions, etc. within the whole. Good structure means the ability to describe the system through the establishment of its structure, i.e., network connections and relations of the system, the dependence of the system behavior from the behavior of its individual elements and the properties of its structure, the interdependence of the system and environment. Hierarchy means that each component of the system can be considered as a system and the analyzed system represents one component of a broader system in this case. The adequate knowledge of the system requires building many different models, each of which describes some aspect of the system because of the principal complexity of each system. Let's describe main system's principles using narrow predicate calculus. This runs as follows.

The principle of integrity is set to items 1 and 2:

1. $\vDash \wedge_{i \in I} P_i(\langle S_\alpha, Q_\alpha, U_\alpha \rangle, \alpha \in \mathrm{A}) \wedge (\exists P)(P(\langle S_\alpha, Q_\alpha, U_\alpha \rangle, \alpha \in \mathrm{A}) \wedge (\neg P(\langle S'_\delta, Q'_\delta, U'_\delta \rangle, \delta \in \Delta)$
   - system S possesses all the properties $\{P_i | i \in I\}$, and there exists at least one property P, such that no one of own subsystems S' of the system S does not possessed P. Thus, the property of integrity allocates system as one having a synergistic effect (at least one).
2. The graph of all relations $\Gamma(S)$ of the system S is isomorphic to the graph $\Gamma(S_f)$ of all links of the system $S_f -$ the final status of the system S.
3. The system structure is understood to be the lattice of its subsystems. Good structure principle is set to item 3:
4. Let $\{a_\beta | \beta \epsilon B\}$ be a set of all inner factors acting on the system S that is determine its behavior. If $a_1 * a_2 * \dots * a_{n_\gamma} = a$, then $f_\gamma^{n_\gamma}(a_1, a_2, \dots, a_{n_\gamma}) = a$, where $\{f_\gamma^{n_\gamma}\ \gamma \epsilon \Gamma\}$ is the set of operations on the set of factors $\{a_\beta | \beta \epsilon B\}$, $f_\gamma^{n_\gamma}$ is n_γ-dimensional operation. There exists one to one correspondence between the class of all real systems and the class of all finite algebraic systems $I(S) = \langle \{a_\beta | \beta \epsilon B\}\ \Omega_S = \{f_\gamma^{n_\gamma}\ \gamma \epsilon \Gamma\} \rangle$ of inner factors of systems.

The principle of hierarchy revealed in the definition 3.

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Let's formalize the goal of a system. The goal of the system S can be specified by a single or n dimensional predicate Q in the following way

$$\bigwedge_{i \in I} P_i \Rightarrow Q$$

or

$$\bigwedge_{i \in I} P_i\,(S) \Rightarrow Q(A_1, \dots, A_n)$$

where $A_1, \dots, A_n$ belong to the domain of predicate Q. Numerical characteristics of a system S or structural characteristics of a system S can be changed but the resulting modified system S' may satisfied P which is the property of the integrity of the system S. That is $P(S) \Rightarrow P(S')$, and therefore, to perform almost all the same functions as the system S, and, ultimately, to achieve the goal Q. Thus the numerical change or structural change of the system S within certain limits does not violate its integrity. This property will be call quasi sustainable one.

Definition 4[1]. The system S is quasi sustainable one in relation to integrity property P if there exists the system S' and the congruence $\equiv_P$ on the system S' such that factor - system $S'/\equiv_P \cong S$.

To determine the class of innovation systems and to study it one should make following definitions. Now let's remind some definitions and theorems from [sorrento]

Definition 5. Let Q be a target of a system S. The set of predicates $\{P_\alpha | \alpha \in \Lambda\}$ is called internal attribute signs of a system S if the formula

$$\bigwedge_{\alpha \in \Lambda} P_\alpha \Rightarrow Q$$

is an identically true formula for S.

Definition 6. Let Q be a target of a system S. The set of predicates $\{P_\beta | \beta \in B\}$ is called external attribute signs of a system S if the formula

$$Q \Rightarrow \bigwedge_{\beta \in B} P_\beta$$

is an identically true formula for S.

Definition 7. Let Q be a target of a system S. The set of predicates $\{P_\gamma | \gamma \in \Gamma\}$ is called attribute signs of a system S if the formula

$$Q \Leftrightarrow \bigwedge_{\gamma \in \Gamma} P_\gamma$$

is an identically true formula for S.

4.2. P – innovative and P-pseudo-innovative Systems

Definition 8. Let S be a system with integrity property P. Then S is called an innovative system with deciding integrity property P if S can be off line in every super system S' such that S is P - pure in S', that is containing it in a way that is not distorted P - connections.

An innovative system S with integrity property P differs from a system with integrity property P higher (not lower than in super system containing it) implementation performance numeric innovative properties, or the fact that analogues of a system with property P does not exist.

The main indicators of innovation are: newness, the degree or level of newness, consumer value, degree of implementation in practice, effectiveness, the presence of a single indicator of efficiency, the phenomenon of "flash" (a synergistic effect) characterizing the beginning of the autonomous work of the innovation system, the graph of all links of all innovations.

Let P be a predicate defining the integrity property of a system S. We shall consider P- pure embeddings in the class of all systems. From [8] we have the following main theorem.

[1] According Anthony Leonard Southern Corner which introduced the concept of quasi – isomorphic Abelian torsion – free group.

Theorem 1. An innovative system S with full realizations of P –connections not distorting P –connections of containing it super system is off line.

Definition 9. Let $S = \{S_i | i\epsilon I\}$ – be a split of a main set of a system $\hat{A}$ with integrity property P, and $P(S_i)$ is true for every $i\epsilon I$. The intersection $\bigcap_{i\epsilon I} S_i = K$ is called the P −kernel of a system $\hat{A}$. As P is closed under intersections then $P(K)$ is true.

In practice $\{S_i | i\epsilon I\}$ are different spheres of functioning operating system $\hat{A}$. In the field of economics and finance it can be: legal and shadow economics, budget and fiscal and monetary and credit spheres, public and corporate finance, and so on. For example, in the field of learning processes one can distinguish the following areas: - the range of subject areas, in which, for example, are studied discipline with interdisciplinary linkages, and the like; - the field of learning technologies, in which, for example, the following technology and generalized educational technologies are included: problematic instruction, concentrated training, developing training, modular training, differentiated instruction, active learning, 's training, and so on; - the field of exit (field performance).

So the P −kernel of a system is essentially its infrastructure[2].

In practice the spheres that are affected when the system $\hat{A}$ is functioning have as a rule non-empty intersection, and thus $\{S_i \cap A | i\epsilon I\}$ is not a split of A. So one can consider $S' = \{S'_i | i\epsilon I\}$, where $S'_i = S_i \setminus \bigcap_{i\epsilon I} S_i,\ i\epsilon I$, instead of $S = \{S_i | i\epsilon I\}$. Then $\bigcap_{i\epsilon I} S'_i = \emptyset$ and $\bigcup_{i\epsilon I} S'_i = A$ and $S' = \{S'_i | i\epsilon I\}$ is a split of A.

Theorem 2. For a subsystem $\hat{B}$ of a system $\hat{A}$ to be an innovative one it is necessary that the main set B of the system $\hat{B}$ contains P − kernel of every its supersystem.

As a consequence we have

Theorem 3. In the economy with the shadow sector system with full implementation of *P* – links cannot work of line, if *P* does not implement any communication of the shadow sector.

Let's introduce the notion of *P*-pseudo- innovative system following the principle of duality.

Definition 10. Algebra $\bar{G} = \langle G | \{f_\alpha^{n_\alpha} | \alpha \in \Gamma\} \rangle$ is called P – pure projective (*P*-pseudo- innovative system) if every diagram with exact *P* - pure string

$$\begin{tikzcd}
 & & & \bar{G} = \langle G | \{f_\alpha^{n_\alpha} | \alpha \in \Gamma\} \rangle \arrow[dl, dashed, "\varphi"'] \arrow[d, "\psi"] & \\
0 \arrow[r] & \bar{B} = \langle B | \{f_\alpha^{n_\alpha} | \alpha \in \Gamma\} \rangle \arrow[r, "\alpha"] & \bar{A} = \langle A | \{f_\alpha^{n_\alpha} | \alpha \in \Gamma\} \rangle \arrow[r, "\pi"] & \bar{C} = \langle C | \{f_\alpha^{n_\alpha} | \alpha \in \Gamma\} \rangle \arrow[r] & 0
\end{tikzcd}$$

that is Im α is P-pure in $\bar{A}$ can be extended to commutative one that is $\psi\pi = \varphi$.

In [ ] we get the following theorem.

Theorem 4. Direct (inductive) limit of *P*-pseudo- innovative systems is *P*-pseudo- innovative system.

The proof of the theorem 4 passes like the corresponding ones in [3].

As a consequence we have

Theorem 5. The system which is at the same time a *P* - innovative and *P* - pseudo – innovative one is degenerate, that is cannot work.

Consequence 1. In order for the *P* - innovative system to function, it is necessary that at list one *P* – property of *P* - pseudo – innovative system would be absent.

The meaning of this consequence runs as follows: the system without flows does not work.

5. The Algorithm of a Complex Estimation of the Efficiency of Functioning of the Innovation System

1. The construction of quantitative indicators describing the functioning of the innovative system. Detection and compliance monitoring of the functioning of the innovative system to its goal.

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2 Infrastructure is a set of interrelated service structures or objects, components and/or provide the basis for the functioning of the system

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2. Identification and monitoring of all links of the innovation system with the external system and its subsystems arising in the process of the functioning of the innovative system.
3. Identification all of internal and external attribute factors of the innovative system. The construction of quality indicators describing the functioning of the innovative system in the form of a graph and the group of internal attribute characteristics of the innovative system. . The construction of quality indicators describing the functioning of the innovative system in the form of a graph and the group of external attribute characteristics of the innovative system.
4. The determination the number of all possible synergistic effects of the innovative system.
5. Building the model of the functioning of the innovative system by its internal and external attribute characteristics.
6. The checking the possibility of increasing the accuracy of the model by introducing the additional factors into the model.
7. Adjustment of control actions to prevent the occurrence of undesirable synergistic effects.

6. Conclusion

The following theoretical results have been already received as applications to Economics and Finance on the basis of the proposed formalization of a notion of a system:
- factors that affect the accuracy of the simulated process or phenomenon in a closed system are revealed;
- the theorem about the description of the financial risks is proved: financial risk of a system is defined by no more than two combinations of the factors defining risk's subsystem of the given system, [9].

For expert systems learning algorithm for database compilation errors when solving problems is built, a theorem about the errors' description is proved, the classification of errors is received, errors are graded on their length. The algorithm jumps to the entry of the decision on the language of narrow predicate calculus write the solution in the language of group theory, which allows to consider the elementary theory of groups of the right decisions and of a group of errors.

In the present work we focus on the algorithm of a complex estimation of the efficiency of functioning of the innovation system.

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Uniform Teaching of Network Simulation Skills in an Engineering Curriculum

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Abstract

Communication engineering technology is changing rapidly. The need for co-existing and seamlessly integrated heterogeneous networks and the currently evolving Internet-of-things technology are among the examples. As an educator, we have to make sure that the curriculum incorporates these changes. We present methods for successful teaching of network simulation skills which are under development in our Communication Engineering curriculum. Simulation is one of the most important teaching instruments in engineering education. It is also a necessary working-life skill since in most engineering industries simulations are usually performed to proof the concept's and/or design's correctness before investing in the development of a product. The main principles of the curriculum are employing uniform and incremental teaching strategies with the aim of achieving the integrated learning outcome. The first step is choosing efficient simulation tools, which can be used in consecutive courses with few add-ons. The selected tools have to be closely similar with tools used in industries so that students can use the acquired skills directly in their future working life with minimum adaptation effort. Simulation models and exercises are developed through cooperation of the involved courses' lecturers and assistants. These ensure the uniformity of the teaching approach, progressive knowledge transfers and skills improvement.

Keywords: *network simulation skills, communication systems engineering, career-life prepardness.*

1. Introduction

Information and Communication Technology is one of the fastest growing and most rapidly developing areas of engineering science. The astonishing rate of development in Information and Communication Technology requires constant examination of engineering education curricula. Moreover, the discipline of Communication Systems is one of the fields of technological sciences where the rate of change is considerably higher than other fields of engineering.

Incorporating a range of pedagogical practices in classrooms is a necessary step for achieving a highly satisfactory learning outcome. The students' acquisition of skills during their ICT education requires a continuous and gradual learning process. Due to the highly technical nature of the field, educators should not advance towards the most complex concepts without making sure that the basic concepts are properly adopted by the students. One way to carefully guide and assist students in their learning process is to include the utilization of simple and flexible learning tools in the education. Network simulators are suitable for use as pedagogical tools and they complement the overall learning process. They allow students to apply the learned theoretical concepts to practice and to experiment with them. For example, students can construct simulated network topologies in the simulators and conduct a number of evaluations and measurements on the network under a projected set of operating conditions.

Network simulation tools are not only widely employed in the academic world but also in the corporate professions. In the industry it is customary to evaluate the suitability of different design alternatives using network simulators before deployment of a real system. For instance, system architecture, technologies, and protocols can be analyzed without the need for any physical infrastructure. They are important tools for decision making since they allow assessing the impact of any decision on the behaviour of the system before being deployed. Thus, network simulation skills are necessary for the future careers of the students and these skills must be taught in a profound manner.

In this work, we discuss efficient teaching of network simulation skills for communication engineering students at undergraduate, graduate and post-graduate levels of study. We will discuss uniform and incremental teaching strategies in context with network simulation skills, required network technologies and their consequences on a student's future career in academia and the industry. The main principles we follow in teaching network simulation skills are uniform and incremental teaching methods. Some network simulators require a steep learning curve which may discourage students and affect the learning outcome. Selection of a few appropriate network simulators which can be used by as many courses as possible is an important first step. In addition to this, following a uniform teaching method along with incremental teaching leads to considerable reduction of the learning load required from students. The uniform teaching principle relies on the use of similar teaching methods by all instructors and ensuring the simulation exercises build on the prior experiences of the students. Simulation exercises are co-designed as a package by involving all instructors with the main aim of fulfilling the overall intended learning outcomes of our Bachelor's and Master's degree programs. In addition to learning outcomes of each course, the instructors have to contribute towards achieving the overall degree level learning goals. The simulation exercises are categorized into modules and each module belongs to a course. This helps in ensuring the uniformity of the teaching methods and the incremental learning progress of simulation skills.

The rest of the paper is structured as follows. Section 2 discusses related work on teaching network simulators. Section 3 presents the targeted learning outcomes from network related courses in our Bachelor's and Master's degree programs. The motivation behind using network simulators and their selection criteria are discussed in detail in Section 4. The proposed uniform and incremental simulation skills teaching approach is presented by showing the acquired skills from each course along with the employed network simulator. Discussion and Conclusions are presented in Sections 6 and 7, respectively.

2. Related Work

A number of efforts have been carried out in improving the learning process through inclusion of simulation exercises. Here we discuss the most relevant approaches related to the focus of the work presented in this paper, that is, network simulation skills.

Gustavo et al. [1] have proposed a constructivist simulation based methodology for teaching mobile communication in the electrical engineering curriculum at University of Valle, Colombia. Students use a simulator developed by senior undergraduate students to learn particular technologies. The assessments of students' results and opinions reveal the effectiveness of the methodology in improving the teaching-learning process. The use of a network simulator to facilitate and enhance the students' learning process in a computer networks course is proposed in [2]. A series of exercises were developed and the benefits of the approach are assessed through surveys answered by students, both before and after the completion of the practical sessions. Montagud et al. [3] analyzed the use of network simulation as a learning resource. The authors have introduced the Packet Tracer simulator in their Telematics Architectures and Networks course, which runs in the second year of studies for Bachelor's degree of Telecommunications Systems, Sound and Image Engineering. The evaluation of this approach has been carried out using a survey taken by students and the results were satisfactory.

Unlike the above methodologies which focus on improving the teaching approach of a single course, we are aiming for the overall degree level learning outcomes. In our proposed uniform and incremental teaching approach, the incorporation of network simulators for aiding the learning process starts from the first communication systems theme course and continues throughout the whole program. The simulation exercises in each course are related to exercises in previous and future courses.

3. Targeted Learning Outcomes

In the Communication Systems Engineering Bachelor's and Master's degree programs there are a number of courses which deal with various network technologies and applications such as computer networks, multimedia networks, internet technologies, and wireless sensor networks. The theoretical content of these courses is essential for solving real-life engineering problems. However, arousing the interest of students, establishing the knowledge and equipping them with the required network engineering skills are also equally important. For this reason simulation exercises which mimic closely the practical implementations of networks are necessary.

The overall degree level learning outcomes of the Master's degree program in terms of technologies related to networking are centered around building diverse career skills with a focus on heterogeneous networks as can be seen in Figure 1. Our curriculum supports the incremental learning approach by starting from basic mainly

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theory based courses followed by core technologies and application oriented courses and finally reaching real world problem based capstone projects. The fundamental, mainly theory based courses which run in the first, second and third year of studies are Basics of Data Communication, Digital Signal Processing and Digital Communications Systems, respectively. From these three courses the students gain knowledge on signal types, characteristics, and their representations for further analyses, digital signal processing techniques and filter implementations, components of digital communication systems along with their functions and design options. At this level the students know the details of how a digital communication system consisting of a transmitter and receiver pair works, and they are able to model it at component level. Also, they are able to carry out performance analysis of digital communication system components and the overall system. The courses under the core technologies emphasize on network technologies, protocols and their implementation issues. The students acquire knowledge on protocol stack layers, standards, protocol processing system design and routing protocols. In the core technologies, the students also go in-depth to protocol processing, especially the IPv4 and IPv6 and the Internet core routing system. In this category, the specific features, design and implementation challenges of these networks are taught. The application oriented courses encompass heterogeneous network types: low-power wireless networks, wired and wireless LANs and multimedia networks. Upon completion of the Sensor Network Systems course, students are capable to make correct design decisions on node architectures and components as well as network topologies. They are also able to devise and/or choose appropriate power management strategies and carry out protocols design and analysis. In addition, they are able to perform performance analysis of a sensor network system. The DSP for Networked Embedded Systems course build on the knowledge acquired from Sensor Network Systems course and focuses on distributed signal processing and self-aware embedded systems implementations. It also covers signal processing techniques for multimedia sensor networks. Multimedia Networks course presents multimedia signals and their requirements for transport as well as high speed networking technologies suitable for multimedia distribution applications. Special attention is paid for high definition television signals and their distributions including home wireless networks. Advanced Internet Technologies course provides knowledge on the global Internet and its increasing importance for the society in various levels. Course presents new technologies for high speed Internet access including fiber optics and high speed wireless access.

All of the above courses have simulation exercises in order to teach students the necessary skills. The assessment of the student's skill as an individual or as a part of a group is a process that has to be continuously done throughout the course. In the assessment process whether the course learning outcomes have been achieved should be checked. The details of the exercises along with the chosen simulators will be discussed in Section 5.

The Capstone project is a study module of 30 ECTS credits. It consists of 15 ECTS of courses (pre-project related issues) and 15 ECTS of project implementation. The aim of the capstone project is to provide students hands-on experiences on design and implementation of real world systems. In Capstone projects dealing with network technologies, the pre-project courses are categorized into three themes: simulation models development, design of communication system components in a simulator, and system modeling and simulation. The students form a group consisting of about three students and can choose one of the themes. They will have a mentor who will guide them when needed and follow up their progress. They have to report the progress of their work to the mentor in a specific period. If a group chooses the simulation model development theme, they are responsible for choosing the programming language and environment, the network type and whether to create the simulation model from scratch or integrate/update with existing models. At the end of the course the team is expected to demonstrate a working simulation model. Also, the accuracy and validity of the model has to be verified. If a group chooses communication system components design, they have to decide what type of communication system they are going to design and its intended application. They have to define the required features of the transmitter, receivers and radio medium (channel), and design the transmitter, the receiver, and the channel in an appropriate simulation tool and validate the correctness of the designs. Depending on the application type, they are expected to add certain features to the components, for example data compression, filtering, and noise removal. The last theme is system modeling and simulation. In this course the students should be able to simulate a complex system consisting of heterogeneous networks and analyze the performance of the overall system. An example of such a system is a health monitoring system. It consists of wearable sensors together forming a body sensor network, home sensor networks, an access point (gateway) to reach a remote healthcare professional, and data transportation facilities from the gateway to a cloud service for storing the monitored data and to facilitate data access by a remote end user. These pre-project courses are the preparation stage for the hands-on implementation projects. To successfully complete these courses the students should use the knowledge and skills they have acquired from the basic theories, core technologies and application oriented courses. In addition to simulation skills, the students gain team work and project management skills.

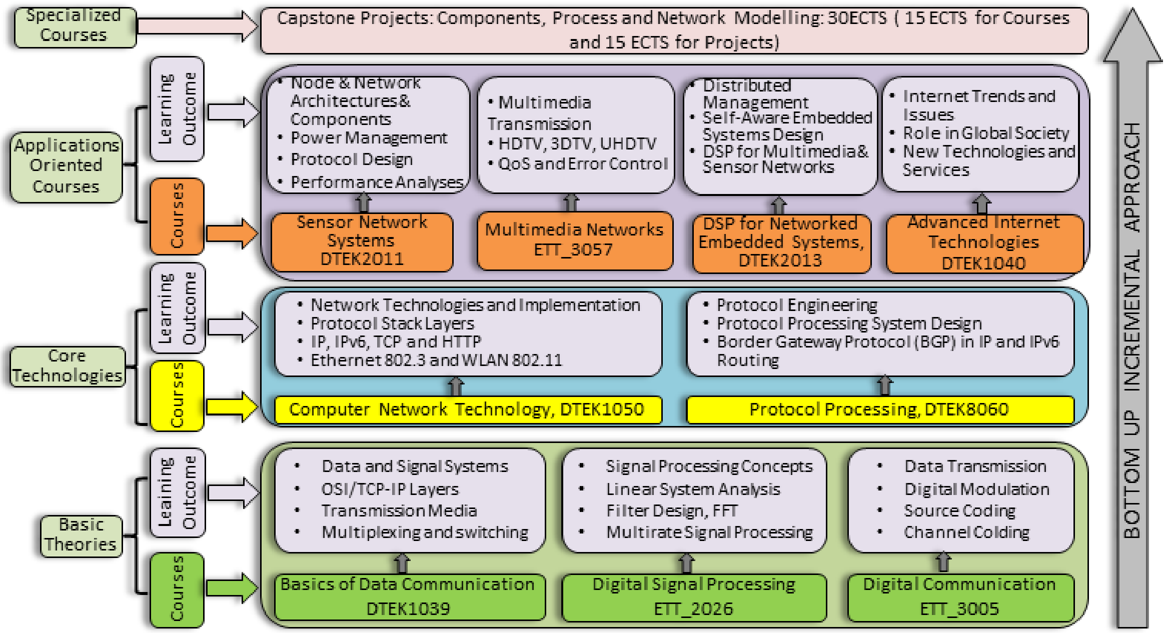

Figure 1. Targeted Learning Outcomes.

4. Selection of Network Simulators

Network simulation tools are widely employed in academic, scientific and industrial work. They are important learning tools that help students to consolidate the knowledge acquired in the lectures in a more flexible and gradual manner. Simulators make it possible to apply the studied theoretical concepts without a need to deploy physical implementations which may be costly and time consuming. Through simulation students can learn how networks must be configured to achieve specific objectives, the basics about functional network architectures, the existing standards and protocols related to the design, and the deployment and interconnection of different network types. The incorporation of simulator based exercises encourages the students to work on the problems independently beyond the scheduled classroom times. If a student is not able to finish the work in the allocated time, he/she can save the configuration files and resume the work later. Instructors can also retrospectively evaluate the configuration files of each student in a more flexible manner which in turn allows them to track the students' progress and to identify possible conceptual shortcomings in the learning process. Students can practice anywhere and anytime especially when open source simulators are used.

As stated previously, network simulation skills are required in a variety of professional careers in the ICT field. Before deployment the appropriateness of the selected architecture, protocols and technologies can be analyzed using simulators without the need for any physical infrastructure. Through simulation, the feasibility of the deployment can be assessed beforehand. Simulations also allow examining the performance and behavior of a running system by monitoring some parameters of interest without interrupting the normal operation of the network.

Network simulators can be classified based on a variety of criteria, for example, whether they are commercial or open-source, or whether they are simple or complex [4]. A simple network simulator should allow a user to, at least, (i) represent a network topology, (ii) specify network scenarios, (iii) define nodes on the network as well as the links between them, and (iv) demonstrate the network traffic between those nodes. Whereas, a more capable network simulator enables users to specify everything, in depth, about the protocols utilized to process network traffic. A Graphical User Interface (GUI) feature also allows users to easily visualize their simulated environment. Some network simulators may be text-based, offering a less visual or intuitive interface, but providing more advanced forms of customization. Other simulators are programming-oriented, enabling users to customize or to create an application that simulates the networking environment for testing. However, using any type of network simulator, at least basic programming skills are usually required. The main reason is that in order to meet the design goals, a student may need to modify some part of available code (for example, related to a specific module or component) and rewrite the code according to the envisioned network requirements.

Open source network simulators have the advantage of availability without cost: students can install open source simulators to their devices to use them anytime and anywhere without being bound to university labs. However,

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most open source network simulators lack systematic and complete documentation. Some of them also lack version control support which may lead to some serious problems and can limit the applicability and life-time of the open source network simulators. Typical open source network simulators include NS-2 [5], NS-3 [6], OMNeT++ [7], Cisco Packet Tracer [8], Cooja [9], and Castalia [10]. We do not discuss available network simulators in detail here because it is not in the focus of this paper. Interested readers can refer for example to [4, 11].

Certain criteria must be taken into account in choosing a specific simulator for teaching courses. Most importantly, ease of use must be considered. It would not be optimal to use an advanced simulation tool due to the steep learning curve. If the simulator is simple and intuitive the technological concepts will be learned more easily. Also, the simulator should provide the students a similar experience to the associated configuration tasks as found in real networks. The software must implement accurate simulation components and libraries to ensure that the simulation can accurately reflect the behavior of the network. In addition, it has to be flexible enough to be adapted to the learning context, so that it is possible to support simulation exercises ranging from the basic theoretical concepts to the most advanced ones found in the target course. The software must also provide a smooth transition towards real networking implementations.

Among the available network simulators, we decided to use OMNeT++, Castalia and Cooja for the network based courses, see Table 1. OMNeT++ (Objective Modular Network Tested in C++) is an open source, modular, extensible, and component-based discrete event simulator that is used to simulate both wired and wireless networks. It is a general purpose simulator that can simulate any network built of a variety of devices, topologies, and components interacting with each other. OMNeT++ simulations can be performed under different user interfaces. Graphical and animated user interfaces are very suitable for demonstration and debugging purposes. Domain-specific functionalities such as support for Wireless Sensor Networks (WSN), wireless ad-hoc networks, protocols commonly used on the Internet, and performance modeling are available in OMNeT++. Castalia is an open source simulator designed for Wireless Sensor Networks (WSN), Body Area Networks (BAN) and networks of low-power embedded devices. Castalia is based on OMNeT++ and it is specifically used to test distributed algorithms and protocols in realistic wireless channel and radio models.

Contiki [9] is an operating system designed for resource-constrained devices such as sensor nodes. It is built around an event driven kernel and supports a full TCP/IP stack via micro-IP (uIP). uIP is the smallest version of a full TCP/IP stack which is designed for tiny microcontroller systems where RAM and code size are extremely constrained. uIP only needs several hundred bytes of RAM and about 5 kilobytes of code space. Contiki devices usually make up large wireless networks for which the development and debugging of software are not easy tasks. Cooja is the network simulator as well as the emulator of Contiki devices. Cooja provides a simulation environment which enables developers to both see their applications run in large-scale networks and in extreme detail on fully emulated hardware devices. The principal design goal of Cooja is extendibility, for which interfaces and plugins are utilized. An interface allows to the designers to observe features of the network such as nodes position, radio transmitter and button. A plugin is employed in order to interact with a simulation, e.g., to control the speed of a simulation, or to watch network traffic conveyed between the simulated sensor nodes. New interfaces and new plugins can conveniently be developed by the user and added to the Cooja simulator. Hence, by supporting various simulation environments in one simulation simultaneously, it is possible to simulate different hardware platforms in heterogeneous networks. Java Native Interface (JNI) is utilized to connect the new simulations with Contiki. This allows simulated applications to be run in a real Contiki system. Thus, by using this method, any simulated application can be run on a real sensor node without any modification.

5. Proposed Teaching Approach

The courses in our curriculum, that convey knowledge of network technology, have a set of simulation exercises and projects which are defined based on real-life examples. The theoretical knowledge obtained by participating in classes (lectures) and by independent work must be applied to the simulation exercises. In this section, the details of the exercise packages and the targeted simulation skills for the courses shown in Figure 1 are discussed.

5.1. Exercise Package

Exercises for all courses shown in Figure 1 are co-designed by the involved course instructors in order to ensure the exercises build on prior knowledge and simulation skills. This strengthens the incremental learning process. The exercise package consists of nine modules where each course has one module. Each module can have up to five exercise sessions.

In Basics of Data Communication, students work on the exercises using MATLAB. The exercise starts with continuous and discrete signal representations as well as analysis. Sampling and quantization techniques for the conversion of analog signals to digital are also demonstrated in the exercises of this course. Basic digital transmission techniques along with design of simplified transmission channels in the presence of noise are also covered in the exercises. In Digital Signal Processing, students practice how to design FIR and IIR filters in MATLAB. Simulation of signal processing algorithms and linear time invariant (LTI) systems are also part of the exercise. In addition, noise modelling and introducing it into the system in order to examine the performance of the designed filters are included in the exercises. The students have to apply the skills they acquired from the above two courses for carrying out the tasks in the exercises of Digital Communication Systems. The exercises of Digital Communication Systems cover the simulation of source modelling and compression techniques, modelling of different channel types, basic digital modulation schemes and receiver designs.

The Computer Network Technology and Protocol Processing courses use OMNeT++ for simulating the tasks of the exercises. In Computer Network Technology, the exercise modules cover network setup and configurations, frame structures, packet capturing and analysis and traffic flow. In the exercises of Protocol Processing, the focuses are on the design of protocol processing systems, protocol formulation and analysis of their performance, routing and the Border Gateway protocol for routing IP and IPv6.

In Sensor Network Systems, the exercises deal with wireless sensor network setup and parameter configuration, simulating different MAC and routing protocols and analysing the performance of these protocols, estimating the power and energy consumption of the network at runtime and emulating different applications in the simulator. The exercises of DSP for Embedded Networked Systems build on the expertise gained in the Sensor Network Systems course. The simulation exercises include implementation of filtering, data aggregation, fusion and compression techniques, multimedia sensor network implementation and analysis of performance and energy source requirements. Both these courses use Contiki as an operating system for the nodes and Cooja for network simulation/emulation. The latter course requires integration of MATLAB with Cooja.

Multimedia Networks and Advanced Internet Technologies courses use OMNeT++ for the exercises. The Multimedia Networks course exercises encompass setting-up of multimedia networks, performing network configurations in order to fulfill application requirements, implementation of error controlling mechanisms, evaluating the quality of service criteria and ensuring quality of experience. The exercises of Advanced Internet Technologies consist of simulations of new technologies such as modeling distribution of 4K signals using scalable video coding over high speed wireless LAN networks shared with a number of IoT devices in a smart home.

5.2. Targeted Simulation Skills

The proposed network simulation skill teaching approach starts from teaching signal representations and goes to simulating large-scale systems consisting of heterogeneous networks. The targeted simulation skills for each course are listed in Table 1 where the incremental gain of skills can be seen. The simulation exercises of the first three courses provide all the required skills for modelling, implementation and performance analysis of the transmitter-receiver pair of a digital communication system. The students gain network simulation skills from the rest of the courses. The major difference between these network oriented courses is the type of the network they deal with (low-power wireless, wireless, and wired networks) and the application purposes of the network. The pre-Capstone project courses enable the students to apply most of the skills they have learned in the prior courses and strengthen their network simulation skills.

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Table 1: Courses, simulators and acquired simulation skills

Courses	Simulators	Acquired Simulation Skills
Basics of Data Communication	MATLAB	• Signal and functions representations • Digital transmission techniques • Signal multiplexing and spreading • Guided and unguided transmission media
Digital Signal Processing	MATLAB	• Filter design, LTI systems, magnitude and phase responses • Time and frequency domain analyses • Simulation of DFT and FFT algorithms • Noise modeling, SNR
Digital Communication Systems	MATLAB	• Digital modulation, receiver structures and design • Source and channel modeling and coding • Basics of Encryption • Performance analyses: BER, SNR, channel capacity
Computer Network Technology	OMNeT++	• Network topologies and architectures • Data format and traffic analysis • IP, UDP and TCP protocols • Analyzing network performance
Protocol Processing	OMNeT++	• Protocol design, processing and analysis • Performance assessment of a protocol processing system • DNS system • Inter-domain routing in the Internet
Sensor Network Systems	Contiki and Cooja	• Sensor networks setup and configuration • MAC and routing protocols customization • Power and energy estimation • Applications emulation
Multimedia Networks	OMNeT++	• Multimedia network setup and configuration • Quality of service • Error control • Performance analyses
DSP for Networked Embedded Systems	MATLAB, Simulink, and Cooja	• Signal processing in networked resource constrained devices • Filtering, data aggregation, fusion and compression • DSP for multimedia processing in sensor networks
Advanced Internet Technologies	OMNeT++	• Scalable video coding • 4K distribution incl. wireless • Internet-of- Things (IoT)
Pre-Capstone project course 1- simulation models development	* MATLAB SystemC Contiki/cooja	• Creating new models • Analyzing model accuracy and validity • Channel modeling
Pre-Capstone project course 2- design of communication system components	* MATLAB Contiki SystemC	• Verifying and analyzing nodes implementation correctness • Examining nodes and their components functionalities and performance
Pre-Capstone project course 2 - system modeling and simulation	*Contiki/Cooja, OMNeT++ MATLAB	• Network simulators integration • Large scale network simulations • Verifying scalability of protocols and algorithms

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** Students choose suitable simulators depending on the project specifications, the list of tools are for suggestion purpose only.*

6. Conclusion

We presented methods for successful teaching of network simulation skills which are under development in our Communication Engineering curriculum. The main principles we followed are uniform and incremental teaching strategies so that deeper understanding of the knowledge behind the simulation and progressive improvement of simulation skills are achieved. Appropriate simulation tools have been chosen based on the intended learning outcomes of the courses, the network simulators availability and their complexity. The exercise package, composed of exercise modules of the courses, is co-designed by all involved instructors. During the co-designing of the exercises the incremental skills development, targeted network simulation skills and the knowledge intended to be conveyed were taken into account. In addition, the pre-Capstone project courses allow students to get experiences of developing network simulation models, designing communication system components as well as simulation and analyses of overall system. All these skills are important for their careers and applicable in their future working life with minimum adaptation efforts. The assessments of the proposed teaching strategy will be carried out in future.

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Portfolio Management Simulation as a Learning Tool

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Abstract

Croatia's financial and capital market is relatively well developed in terms of providing investors and potential investors with access to trading domestically and abroad. The investing infrastructure is by and large in place and is aligned fully with the EU standards. However, most of the active and particularly would-be investors received none or very limited financial and investment education. This results in inferior financial skills and less than adequate asset allocation for the Croatian average investor. A cumulative effect of financially suboptimal literacy of investors has a nation-wide negative impact with less than efficient capital market being only one of its manifestations. With the surge of easily available portfolio management simulations such as Stocktrak, investment and financial concepts are much easier to grasp, understand and implement in the real investment world. Stocktrak simulation proved to be an invaluable supplement in raising financial literacy among finance students and those willing to manage their finances. The paper explores advantages of using the simulation as a supplemental learning curve and demonstrates its importance in dismantling cumulative investing illiteracy in Croatia, which is prerequisite for better asset allocation and the first step towards a more efficient domestic capital market.

Keywords: *Investments, Portfolio Management, Learning Tool, Financial Skills, Financial Literacy, Simulation, Education, Croatia, Southeast Europe*

1. Introduction

The paper explores advantages of using the simulation as a supplement that boosts the learning curve in investments and demonstrates its importance in dismantling cumulative investment and financial illiteracy in Croatia. Raising awareness of managing personal finances combined with a higher degree of financial and investment literacy among students in Croatia, who are considered soon-to-be investors is prerequisite for better asset allocation and the first step towards a more efficient domestic capital market.

Investors in some of the markets in the South East Europe (SEE) are still lacking easy and efficient access to both local and global capital markets (e.g., Albania, Kosovo). At the same time investors in comparatively more advanced markets (Slovenia, Croatia, Romania, Serbia, Bulgaria) in SEE region have been able to use stock exchange services during the last two decades. This period appears to be insufficient for increasing households' exposure to equity markets in these countries. For illustration purposes – it took several decades for US households to reach exposure that is well above 50%. Namely, exposure to equity investments of US households currently stands at around 68% up from around 25% during 1950s.

As a result, asset allocation in countries whose households are insufficiently exposed to equity investments is suboptimal. The reasons for such a low exposure obviously include factors such as low GDP per capita, lack of experience, and financial illiteracy. The focus of this paper is overall importance of financial education with emphasis on being supported by portfolio management simulations such as Stocktrak and resulting financial literacy of the population/students in Croatia where investing infrastructure and laws are aligned with those of other EU markets.

2. Research paper

Most of the Croatian active investors and particularly would-be investors received none or very limited formal financial/investment education. This obviously results in inferior financial skills and less than adequate asset allocation for the Croatian average investor. A cumulative effect of financially less than literate Croatian investors results in a nation-wide negative impact with inefficient capital market being only one of its manifestations.

3. Significance of the research

The paper offers findings based on the data and experience gathered over the last ten years of using a portfolio management simulation as a teaching tool at undergraduate level. The significance of the paper resides in its results that can be used by a wide range of education analysts, business school officials, and government officials who deal with envisioning and steering the higher education curricula that pertains to the field of finance.

Furthermore, the paper can serve as a stepping stone for future research to be conducted and which will be based on the findings and results of this one. Some of the research questions that could be researched while based on this paper's results include deciphering the relationship between the Croatian student body and its exposure to the capital markets, understanding average risk aversion of Croatian students in relation to equity investments, and portraying the students' current risk-return expectations.

4. Steeping the learning curve by the simulation – briefly on how it works

Each student manages their own portfolio, which is denominated in any hard currency or their mixture – depending on the students' preferred currency exposure. Students are "given" 1 million USD which they can invest in any of many assets via major stock exchanges in the world. The simulation tracks the student's portfolio (Picture 1.) on a daily basis. Students benefit from real-time, streaming platforms that feature global equities, bonds, options, futures, commodities and more. Students have also their private contests for their classes and at the same time compete with appropriate benchmark indices by selecting common trading dates, initial cash balance, and many other trading parameters.

My Portfolio

Welcome back, ZSEM-INVESTMENTS-2015-a!

Snapshot	
Currency	USD
Portfolio Value	$974,774.32
Portfolio Ranking	4/0
Buying Power	$410,254.98
Portfolio % Return	-2.52%
Available Cash	$0.00
Interest Earned on Cash	$1,654.66
Credit Balance	$12,160.90
Interest Charged on Loan	$3,516.24
Loan Balance	$205,362.51
Accrued Interest Earned on Bonds	$0.00
Market Value of Long Positions	$1,180,043.23
Margin Requirement	$153,018.00
Market Value of Short Positions	$12,146.50
Trades Made/Remaining	44/256

Figure 1. Portfolio Snapshot

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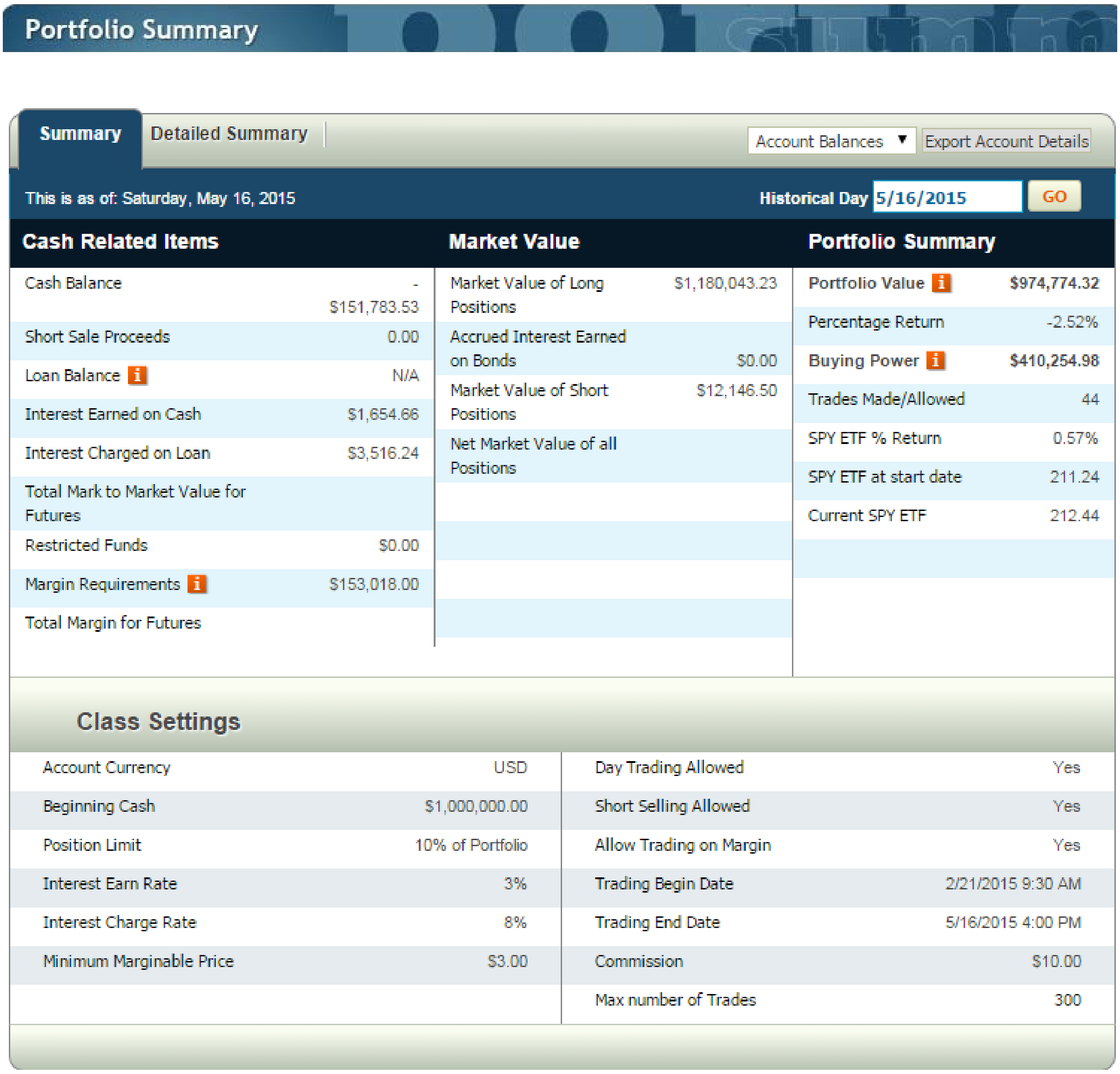
Over the course of fifteen weeks, students practice trading strategies, compete with the chosen benchmark indices while handling day-to-day transactions and posting real-time bid/ask order executions via 50+ global exchanges. Students learn to use a full range of order types including: Market, Limit, Stop, Trailing Stop $, Trailing Stop %. An example of a Portfolio Summary is depicted in the Picture 2 below while Picture 3 provides a graphical discrepancy between the portfolio performance and its benchmark index. These are only some of the many features that the simulation provides to its users.


Portfolio Summary

Summary | Detailed Summary | Account Balances | Export Account Details

This is as of: Saturday, May 16, 2015 — Historical Day 5/16/2015 GO

Cash Related Items		Market Value		Portfolio Summary	
Cash Balance	-$151,783.53	Market Value of Long Positions	$1,180,043.23	Portfolio Value	$974,774.32
Short Sale Proceeds	0.00	Accrued Interest Earned on Bonds	$0.00	Percentage Return	-2.52%
Loan Balance	N/A	Market Value of Short Positions	$12,146.50	Buying Power	$410,254.98
Interest Earned on Cash	$1,654.66	Net Market Value of all Positions		Trades Made/Allowed	44
Interest Charged on Loan	$3,516.24			SPY ETF % Return	0.57%
Total Mark to Market Value for Futures				SPY ETF at start date	211.24
Restricted Funds	$0.00			Current SPY ETF	212.44
Margin Requirements	$153,018.00				
Total Margin for Futures					

Class Settings

Account Currency	USD	Day Trading Allowed	Yes
Beginning Cash	$1,000,000.00	Short Selling Allowed	Yes
Position Limit	10% of Portfolio	Allow Trading on Margin	Yes
Interest Earn Rate	3%	Trading Begin Date	2/21/2015 9:30 AM
Interest Charge Rate	8%	Trading End Date	5/16/2015 4:00 PM
Minimum Marginable Price	$3.00	Commission	$10.00
		Max number of Trades	300

Figure 2. Portfolio Summary

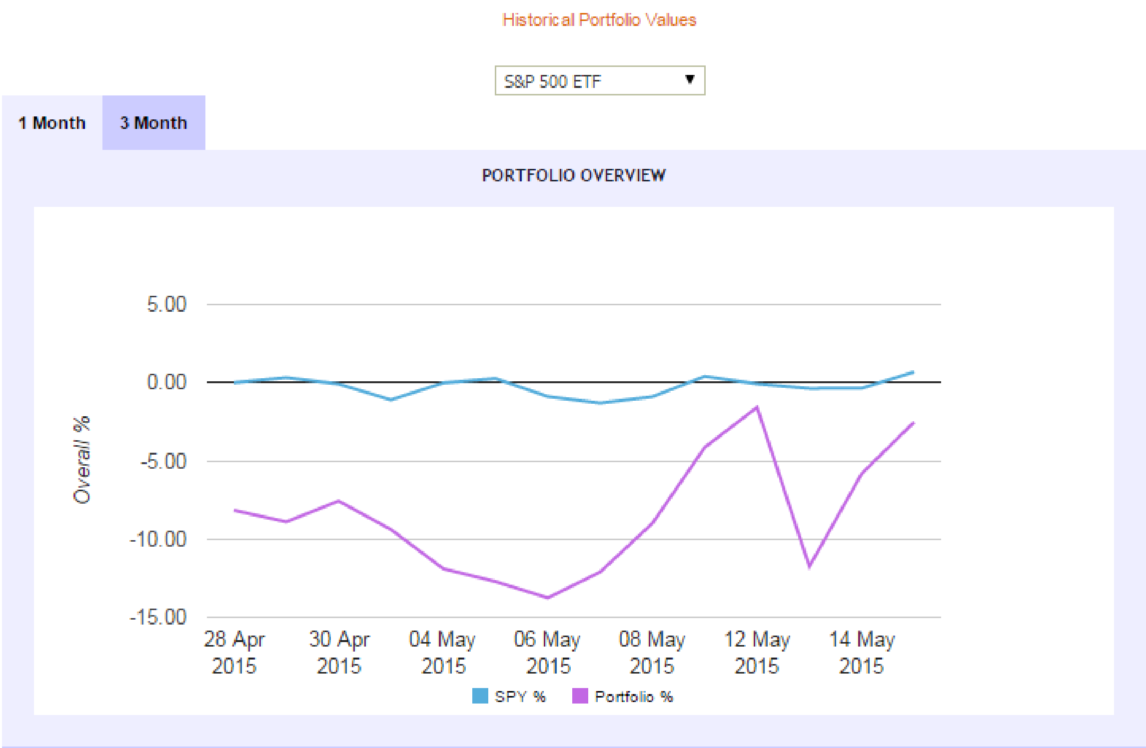


Figure 3. Portfolio vs. Benchmark Return

5. Research methodology

The research methodology used in the paper is qualitative. Over the last ten years the undergraduate students who were taking Investments course would fill out questionnaires with questions on basics of investments and finance prior and after using the portfolio management simulation. The discrepancy in understanding concepts of investing and issues pertaining to optimal asset allocation shows the impact of using the portfolio management simulation for educational purposes.

Presented below are merely some of the questions that the students answered prior and after having participated at the Investments course in which they used Stocktrak portfolio management simulation for fifteen consecutive weeks.

1. How would you rate the degree of your understanding and knowledge with respect to equity instruments?
2. What is the difference in your knowledge and understanding of equity markets and importance of personal financial and investment discipline prior and after using the portfolio management simulation for the last fifteen weeks?
3. According to your preferred risk-return expectations and risk aversion profile, what kind of asset allocation you regard as an optimal one?

6. Results and interpretation/conclusion

With the surge of easily available portfolio management simulations such as Stocktrak, investment and financial concepts are much easier to grasp, understand and implement in the real investment world. Portfolio management simulations provide a risk-free and hands-on approach to acquiring investment knowledge and portfolio management experience. The Stocktrak simulation appears to represent an invaluable supplement in raising financial literacy among finance students and more broadly among those willing to manage their finances utilizing the capital market infrastructure. As a result, the students who actively used such an educational tool can be expected to tap the investment arena much sooner than their peers who have not been exposed to a similar education. This in turn translates into a longer investment horizon for the former ones with arguably more meaningful investing experience and better opportunity for securing their old age income.

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Bringing this knowledge and experience to the national level of rating financial literacy, it is clear that those who used simulations have more realistic risk-return expectations as well as somewhat better aligned risk aversion, i.e. those students with experience tend to be less risk averse in their young age while becoming increasingly risk averse as they approach their golden age. This again translates into better asset allocation for individuals and if the nation is composed of individuals who understand peculiarities of equity and fixed income markets (that can be observed by investing via simulation at an early stage in life), the asset allocation is theoretically approaching its optimal point also on a national level.

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New Teaching Methods

ICEE 2015

Integrated Teaching Methodology of Programming Logic and Statistics

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Abstract

The Programming Logic and Statistics are fundamental disciplines to performing tasks in the areas of Engineering and Computers. The development of skills in both areas contributes significantly to training professionals. As long as the Statistic allows to process data, facilitating their understanding, the Programming Logic organizes the implementation of activities/routines and helps in solving complex problems. The use of the R language of programing in the methodology presented in this work allows the visualization of data, and it was used for the integrated development of statistical calculations and graphics, working with the main topics of statistics and programming. This paper presents a methodology to teach Programming Logic and Statistics, in an integrated view, using the R language with a case study focused on monitoring energy consumption. The case study shows how available data at the Educational Institution have been studied, allowing the contextualization and better learning of the subjects covered. This model can be used in other disciplines.

Keywords: *Teaching Methodology, Statistics, Programing Logic*

1. Introduction

In Engineering and Computer, the disciplines of Programming Logic and Statistics are fundamental to the formation of good professionals, able to carry out the various types of tasks.

Learning Programming Logic allows the student a new way of looking at things around him from the pattern recognition and identification of cause and effect. These characteristics have been greatly needed in all areas, especially in the Exact Sciences area.

Statistics is a science that studies and researches the collection and processing of data in order to facilitate their interpretation for decision-making. Statistical methods have emerged as a mix of logic, science and technology to be used in the solution and research of problems in several areas of human knowledge. Modern statistical brings the quantitative and observational character, which aims to establish the interpretation of experiments and observations of the phenomena of nature and society.

Both Statistics and Logic Programming have their importance in the formation of people in engineering and computing. While the first allows the processing of data and facilitates their understanding, the second organizes the execution of activities, assisting in the resolution of complex problems. This knowledge is complementary, can be synergistically used to solve or, at least, alleviate, many problems in society.

In this perspective, this paper presents a methodology for teaching Programming Logic and Statistics using the R language with a focused case study on energy consumption monitoring at the Federal Institute of Education, Science and Technology Bahia Campus Camaçari (IFBA - Camaçari). This study identifies, from various types of charts, the months in which there is a greater consumption of electricity, from an analysis of committed resources in these months, make plans to reduce the use of electricity. The case study demonstrates the potential of using precepts of Statistical and Programming Logic when applied together from the R programming language.

2. The R Programming Language

The use of statistical packages to analyze a large volume of data is extremely important with regard to the analysis and interpretation of results. It is common to find tools for working with these packages, however, they are relatively expensive. In this context, R appears as a software in the public domain, free and can be used for general data analysis. One of these tools is the programming language R.

R was created in 1993 by Ross Ihaka and Robert Gentleman, statistics teachers of the department of the Auckland University, New Zealand. Due to the fact R is a Free Software and in accordance with the terms of the GNU GPL (General Public License, the Free Software Foundation's), the language is a product of a collaborative effort of people in various parts of the world.

The R Programming Language is a clear example of the potential that is obtained joining Statistical aspects with the applications development. By using R is possible to do various types of data analysis and display these on the form of graphs, of all kinds.

3. Methodology

The methodology proposed in this paper is shown in Figure 1 below. The use of the R language serves as a support for teaching through real life case, facilitating the teaching-learning process.

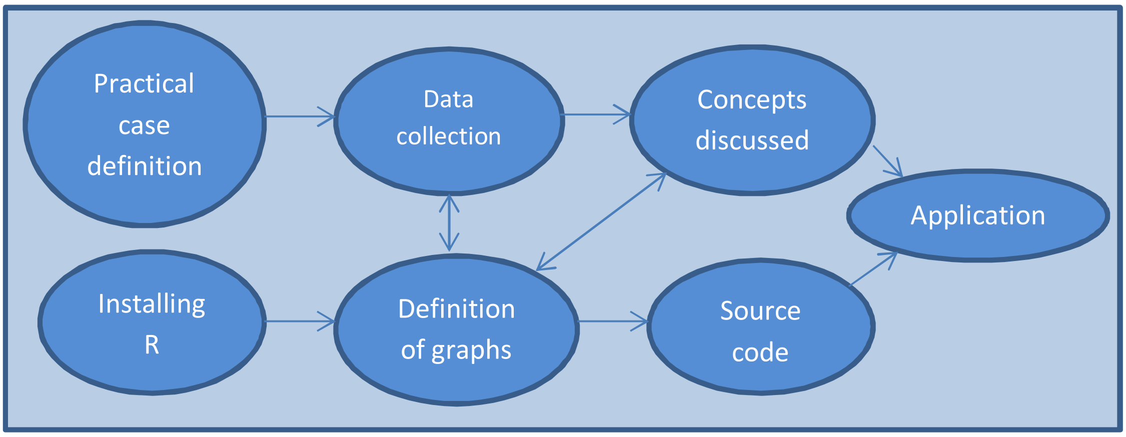

Figure 1 - Teaching Methodology Using R

For this research, the electricity account of the IFBA - Camaçari had been used in the period from 01/2013 to 12/2014 and the objective was to verify the use of these institution data to set the next year's budget. The most important data collected in the account were used in this study and are shown in Table 1 below.

Table 1 – Data used

N°	Data used
01	Active consumption
02	Active consumption (kW / h)
03	Annual demand
04	Active of Overtaking demand
05	Corrected Annual demand
06	Excess reactive consumer
07	Federal Taxes
08	Total Reactive consumption (Minimum and Maximum)
09	Value of Accounts

With the data tabulation, graphics using the R programming language were developed. The following charts were developed:

Figure 2: Barplot - Consumption of the Year;
Figure 4: Plot - Consumption Value;
Figure 6: Barplot - Maximum and Minimum Active consumption;

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Figure 7: Pie - Consumer / Demand;

During the construction of each graph, teaching aspects of Statistics and Programming Logic had been listed. These aspects are presented below, from the identification of the concepts of each discipline.

4. Pratical Case Study

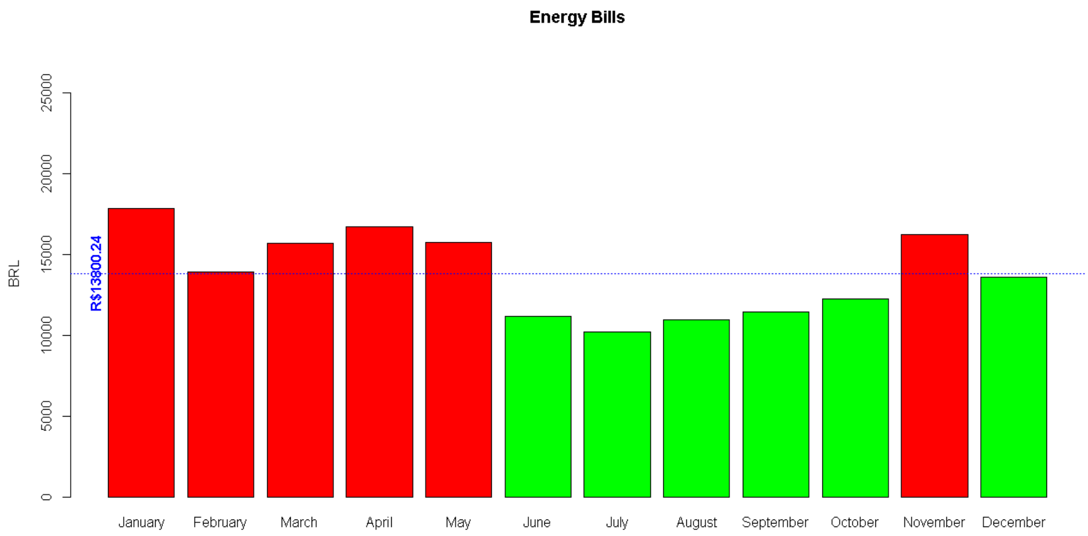

Figure 2: Consumer Value of the Year

The Figure 2 presents the electricity consumption value of the year 2013. It calculates the annual average (blue line) and distinguishes by color the months, red for those that were above average and green for those that stayed below.

```
tabela <- read.table(file.choose(), header=TRUE)

media <- signif(mean(tabela[,2]), digits=7)

barplot(
    tabela[,2],
    names.arg=month.name,
    main="Energy Bills",
    ylim=c(0,prod(media ,2)),
    ylab='BRL',
    col = ifelse(
            (tabela[,2] > media),
            'red',
            'green'
        )
)

abline(
    h=media,
    lty='dotted',
    col='blue'
)

text(
    0,
    media,
    paste('R$', media, sep=""),
    font=2,
    col='blue',
    srt=90
)
```

Figure 3: Barplot - Consumption of the Year

In Figure 3 is used some concepts of programming logic, sequential structure, decision-making structure, data structure, vector/matrix and parameter passing.

Besides them, there are also the concepts of statistical data tabulation, mean values and condensation of these on the form of a bar chart, which shows the proportional greatness to the size according to its caption bar.

On the graph shown in Figure 2, it is possible to identify the months when the consumption value came higher and, from an internal review of resources committed during that month, was possible to trace consumption reduction plans for the coming months.

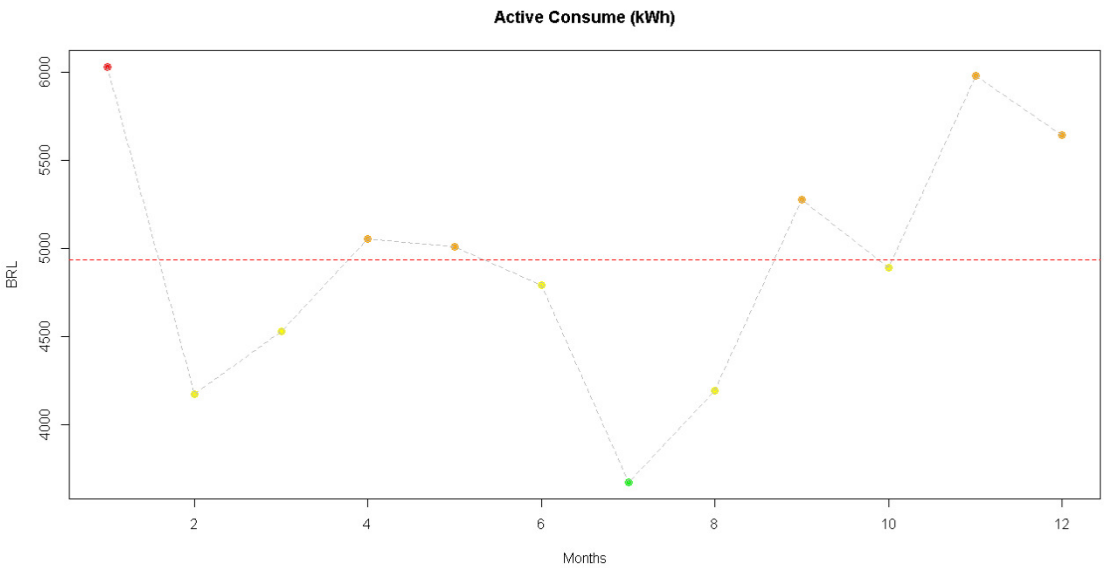

Figure 4: Consumption Value

Figure 4 represents the value of the asset consumption in kilowatt / hours spent in each month. The annual average is shown in a red line and the points are colored according to their position are calculated. The maximum and minimum values are in red and green, respectively. Furthermore, the others take the orange color for a value equal or greater than the average, and yellow when their value are below the average.

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```
1  ca1 <- read.table(file.choose(), header=TRUE)
2
3  media = mean(ca1[,4])
4
5  plot(
6      1:12,
7      ca1[,4],
8      pch=19,
9      main="Active Consume (kWh)",
10     ylab="BRL",
11     xlab="Months",
12     cex=1.2,
13     col=ifelse((ca1[,4] == max(ca1[,4])),
14         "red",
15         ifelse((ca1[,4] > media),
16             "orange",
17             ifelse((ca1[,4] == min(ca1[,4])),
18                 "green",
19                 "yellow"
20             )
21         )
22     )
23 )
24
25 lines(1:12, ca1[,4], type="o", col="gray", lty=2)
26
27 abline(h=media, col='red', lty=2)
```

Figure 5: Consumer Value (kW/h)

In Figure 5, the same concepts in Figure 2 are used. However, there is the use of the decision structure if/else in a pipeline fashion and sequences (line 6 and 25). Statistically, the evolution of data can be shown in more details by the dashed line in Figure 4.

This graph can be used in a complementary manner to that shown in Figure 1, and provides details on consumption, allowing analyzing the consumer with a more specific look to propose in the future, reducing measures in consumption.

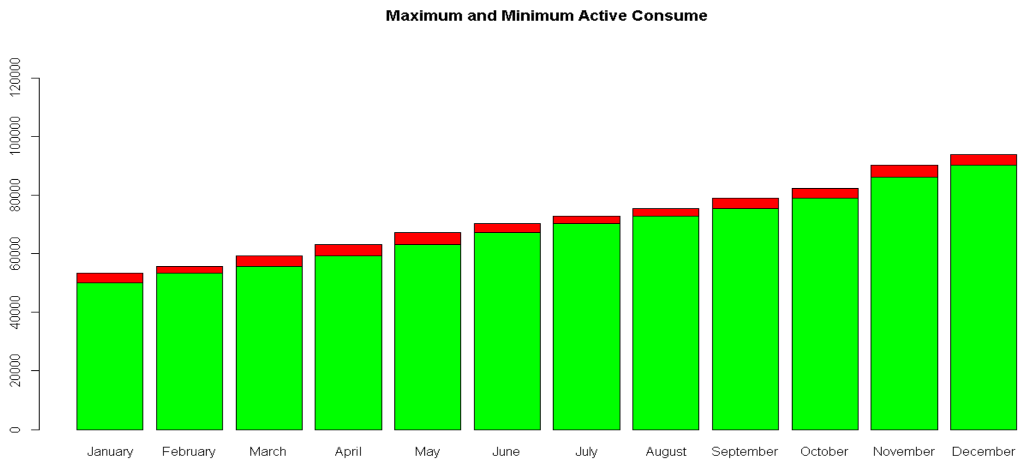

Figure 6: Maximum and Minimum Active Consume

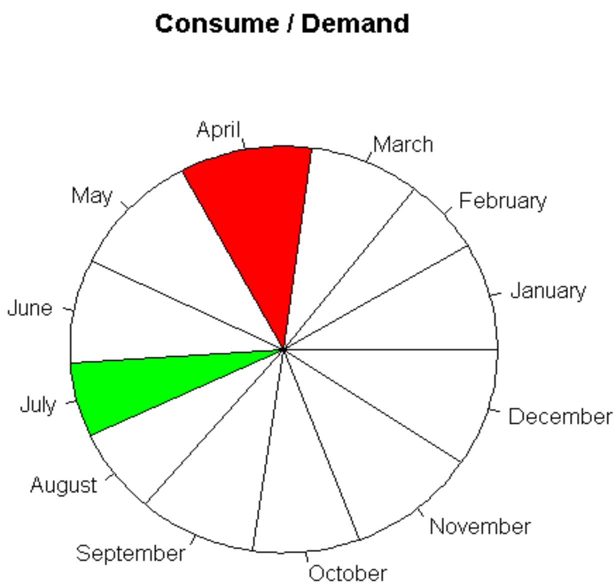

Figure 7: Consume/Demand

The Figures 6 and 7 are generated by the same algorithm in R (Figure 8). The function of the first graph presents the active consumption (maximum and minimum) for each month: red and green, respectively. The second graph shows only the relationship of months, red coloring the month with the highest consumption and green coloring the month with the least consumption.

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```
consumo <- read.table(file.choose(), header=TRUE)

barplot(
    consumo[,3],
    names.arg=month.name,
    col='red',
    ylim=c(0,max(consumo[,3])*1.4)
)

par(new=TRUE)

barplot(
    consumo[,2],
    names.arg=month.name,
    col='green',
    ylim=c(0,max(consumo[,3])*1.4)
)

title("Maximum and Minimum Active Consume")

windows()

pie (
    consumo[,5],
    month.name,
    main = "Consume / Demand",
    col=ifelse((max(consumo[,5]) == consumo[,5]), 'red',
        ifelse((min(consumo[,5]) == consumo[,5]), 'green', 'white')
    )
)
```

Figure 8: Pie/Bar plot - Maximum and Minimum Active Consume

The Figure 8 introduces aspects of image overlay via source code because it actually generates two bar graphs (one for the active maximum consumption, and one for the least, that overlaps the first), and uses the same structures of Figures 3 and 5. Statistically, it introduces the pie chart, where each sector of the circle is proportional to the value it represents.

The use of these graphics can collaborate with the development of electricity cost reduction plan. Despite the focus of this project be the IFBA - Camaçari, these algorithms are easily applicable to other contexts.

Below, are listed the concepts that this paper had covered:

- Logical Programming:
  - Sequence Structure: implementation structure of algorithms in which the steps are performed in an orderly fashion, in the case of programs, line-by-line;
  - Control Structure (Decision with if/else): structure in which an algorithm execution flow can be changed according to the truthfulness of a logical expression;
  - Data Structure (Vector / Matrix): Structure comprising data of the same type on the same identifier;
  - Functions: Code snippets or routines to be performed more than once in the body of the algorithm.
- Statistics:
  - Population: full set of data of a same type to be evaluated;
  - Sample: A subset of a population;
  - Graphics: Graphical representation of data from a population or sample. The types of graphics can be varied, ranging from the bar chart to scatter, pie or others;
  - Average: is the arithmetic operation that divides the sum of a list of values by the number of these values;
  - Tabulation: collected data interpretation.

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According to the graphics and above codes, we can catch a glimpse of the potential of R Programming Language in the teaching of Statistics and Programming Logic. This tool permits the main aspects of both areas to be studied.

5. Conclusions

The importance of Statistics and Programming Logic in the training of professionals in the fields of Engineering and Computer was demonstrated in this study. It could be seen that this credit is due to the benefits that each of these knowledge can have on the Engineering and Computing student.

In statistics, it is common to come across some concepts or activities as the Data Tabulation, Population, Samples, Variables, Medium, among others. All these concepts aim to condense a large amount of data on the form of graphs, in order to reduce the complexity of interpretation, thus, information can be easily collected about a particular problem.

In programming language there are concepts such as Sequence and Control Structures (Decision and repeat), plus there are also data structures (vectors and / or arrays), functions, variables, among many others. When implemented according to a logic, all this concepts have the potential to solve many problems.

The perspective of this paper, was conceived through a tool to R language that brings together the best aspects of programming and statistics with great potential to improve the teaching-learning process and be also a great tool in professional activities. The R learning also involves learning Programming Logic and Statistics. Its application to problems can bring many benefits, such as energy monitoring study presented in this study, which can help in a notable reduction in electricity costs.

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Engaged STEM Learning using Catapults

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Abstract

This paper describes one element of a year-long module for mechanical engineering students that is designed to enhance student engagement and improve professional skills. This mini-project embraces the concept of 'enquiry based learning' within a challenging student-centered team project. The intensive and competitive project was scheduled early in the first semester as a vehicle to assist students to adjust to their new surroundings at a time when there were no other lectures or classes. The 160 strong cohort was divided into tutorial teams of 6 and started with a review of the mathematical concepts related to simple kinematic systems and the laws of motion. Teams were then exposed to designing, manufacturing and testing a floor mounted catapult and competing to out-perform others through their efforts. Strong bonds became apparent among team members and the willingness on the part of many was shown to work beyond normal class hours were observed because of the exciting and motivational challenge. An online survey provided evidence that, in addition to substantial social benefits, the exercise proved a powerful vehicle for enhancing practical understanding of fundamental mechanics that had been revealed as generally lacking in freshers.

Keywords: *Teamwork, motivation, enquiry based learning, engagement.*

1. Introduction

The transition to higher education can be problematic and it is known that "Effective transition can help to improve rates of initial retention and ongoing success." [1] The Higher Education Academy surveyed a large number of students who had withdrawn early from UK universities [2] and cited poor quality of the learning experience as one of the major reasons and this is defined for us by the students own perceptions. Some pointed to their sense of isolation. For many, this was associated with large-scale lectures that allowed little, if any, interaction with academic staff or fellow students. Some commented on the impersonal nature, the difference between University and secondary school styles and the presumption that lecturers expected students to adapt instantly to their mode of delivery. Others commented on the lack of opportunities to make friends on their course or of intimidating or unapproachable staff. This paper proposes and investigates a possible strategy to address these concerns by introducing significant elements of Enquiry Based Learning (EBL) at the beginning of the degree programme to supplement, explain and inspire study of the more traditional scientific elements that continue alongside it. Enquiry-based Learning is a broad umbrella term to describe approaches to learning that are driven by a process of enquiry. The tutor establishes the task and supports or facilitates the process, but the students pursue their own lines of enquiry, draw on their existing knowledge and identify their learning needs.

The transition into higher education means that many students have to come to terms with an approach to teaching and learning that is markedly different from their previous experience. The first year is one of reorientation, and some students manage this more successfully than others. This paper describes one element of a compulsory Engineering Principles and Professional Skills (EPPS) module for mechanical engineering students, introduced 5-years ago, that embraces the concept of 'enquiry based learning' (EBL) throughout the first year. Student-centred projects and skills workshops sit alongside and provide motivators for a broadly traditional first-year curriculum. A break from normal didactic delivery takes place in the fifth week of the first semester to encourage and excite students who were evidently still adjusting to university lectures: it had been observed that some were starting to become unmotivated and inert. Providing motivators, in addition to those gained by the award of marks is a key challenge. Hertzberg's two-factor theory [3] suggests that, in the workplace, additional motivators are needed and that 'hygiene factors' or potential demotivators should also be addressed. There is no reason to suppose that people behave any differently in education. Interpreting Hertzberg's work suggests that to make study tasks motivating, participants must be given responsibility for it and that the deliverables should provide sense of achievement. To improve 'hygiene', we should remove excessive bureaucracy and paperwork, provide effective but non-invasive support, create a culture of dignity and respect for students and provide 'meaningful' work tasks. In other words, give students real ownership and involvement in their learning.

2. Defining Motivation

Effective engineering education requires the integration of knowledge, skills, comprehension and implementation, thus making engineering education, perhaps uniquely, challenging. Top students are observed to progressively mature through the course of their degree programmes: from the initial position where 'life begins when work ends' to life and work being indelibly associated where they become emotionally attached to and motivated by their work. The task, however, is to make this happen earlier and to a wider group with a 21st century skills set. In 'When Teaching becomes Learning' [4] wrote that motivation is already present in learners but it is a matter of creating situations that enable learners to become actively engaged and to use these experiences to reinforce the necessary fundamental knowledge and skills to support the science.

Extrinsic motivators such as coherent marking and grading schemes are generally well understood but students often have little accurate knowledge about the satisfaction and rewards their education may bring to them in later life. According to Herzberg, intrinsic motivators and extrinsic motivators have an inverse relationship: intrinsic motivators tend to create motivation when they are present, whereas extrinsic motivators tend to reduce motivation when they are absent. Intrinsic motivators represent less tangible, more emotional needs, such as challenging work, recognition, relationships, and growth potential. Extrinsic motivators tend to represent more tangible, basic needs. Motivators driven by enjoyment or curiosity in the task itself are observed to have little pull in lengthy and dull theoretical lecture courses whereas it is well known that pedagogies based on student-centered learning provide strong drivers towards learner autonomy and a mindset that promotes success.

The Higher Education Funding Council for England (HEFCE) provides evidence [5] for improved engagement through intra-modular interventions and modified teaching and learning styles within instructional units (modules). In recent years, researchers have formed a strong consensus on the importance of engaged learning in schools and universities. Recognition of the changing needs of the 21st century, stimulated the need for definitions of engaged learning. Jones, Valdez, Nowakowski, and Rasmussen [6] described such learners as self-regulated, able to define their own learning goals and evaluate their own achievement. They are energized by their learning; their joy of learning leads to a lifelong passion for solving problems, understanding, and taking the next step in their thinking. These learners are able to transfer knowledge to solve problems creatively. Engaged learning involves being collaborative: that is, valuing and having the skills to work with others. The researchers defined further indicators of environments where engaged learners will develop and thrive: where there are authentic, challenging multidisciplinary tasks and where there is performance-based assessment. Successful, well-motivated learners are responsible for their own learning.

In 2012, the first author undertook an international research project, visiting 14 Higher Education (HE) Institutions across three continents, interviewing staff and students. The results lend weight to the above arguments. Willmot [7] concluded that the biggest motivating factors were quality assignments; in particular, those where students were stretched and allowed to exercise creativity. Many students had talked about the 'value' of their assignments, at least, their perceptions of value. They commonly used phrases like 'real world', 'practical', 'useful', 'real life applications', and 'industry related' to describe those that engage and spoke of 'text book problems', 'theoretical work' , 'step-by-step laboratories', and 'just to pass the exam' as negative drivers. This work, sponsored by the UK Higher Education Academy, was a powerful driver for introducing the activity outlined below.

3. Parallel Enquiry Based Learning

Attendance levels at lectures were steadily falling and coursework was mostly submitted but tutorial sheets remain largely incomplete. Typically text books appeared to be underused and lecture notes were seen to be filed away, unread by a sizeable proportion of freshers, only to appear a few days before the examination. Apart from the inevitable poor performance, the lack of participative learning had a negative effect on motivation and students who began to get behind, rapidly fell into a cycle of unhappy disengagement in the belief they might never catch up. A significant group of students were clearly unexcited by the courses and didn't know what was really expected of them.

It was a combination of a rising failure/withdrawal rate together with the realisation that young people arrive at university with very a different attitude and range of abilities to those of their forebears that drove the movement for change on the Mechanical Engineering degree programme at Loughborough University in 2009. The ideas that were adopted are founded in the widely known constructivist educational theory where learners are invited to construct knowledge for themselves, become actively involved in their community and learn how to learn while they learn. The several EBL tasks around which the module was built were designed to be authentic and challenging; generating a degree of creativity and competition and promoting real motivational value in an

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unconstrained environment. An external evaluation of the whole module has previously been published in the Journal of Engineering Education [8]. Naturally, the various EBL tasks have been developed and refined over the last five years and the most recent catapult project assignment, described below, postdates this review.

4. Project Week

Students, initially excited by thoughts of technology and machinery had arrived at university to find they were sitting in lecture theatres for long hours and spending their evenings working through problem sheets that closely resembled their familiar, but not much loved, homework from high school, the previous year. With interesting major projects still apparently years away, it is no wonder that some were considering if this was right course for them. 'Project Week' was introduced half-way through the first term at the time when enthusiasm had apparently begun to wane. Lectures were removed from the timetable that week and students were to tackle intensive stimulating challenges.

4.1. The Catapult Competition

A trebuchet was a machine used in medieval siege warfare for hurling large missiles and the challenge would be a variation on this theme, in miniature. Unlike Roman siege engines that were generally powered by a falling weight, the model trebuchets, or catapults were powered by extension springs and the missiles were balls of Plastercine modelling clay, of varying mass, revealed on the day of the competition. While the design of mediaeval artillery was limited to trial and error, due to a lack of engineering knowledge and manufacturing technology, the challenge here was to demonstrate that Mechanical Engineering students can do better through the use of fundamental engineering knowledge and practice. Each team will be challenged to design and build a catapult, capable of firing fixed-mass projectiles accurately and repeatedly over a set distance.
There were two competitive challenges: (i) to fire a series of projectiles 3m across a room to land accurately onto a horizontal, circular 1.4m diameter target (see figure 1) and (ii) to simply propel a 50g projectile as far as possible. The projectiles for the target shoot would be of several different weights between 15g and 60g, announced on the day of the competition.

With 28 teams in play and limited facilities, managing and monitoring the teams was not easy but a deliberate policy of minimum intervention was adopted once the ground rules had been established. At all times, there was at least one member of staff available to offer support on request. And workspaces had been pre-booked. The competition took place on the final day of the week and all teams were given specific time slots to demonstrate the performance of their machines.

The first four days of the week would take the students through four distinct stages of the project leading up to the competition and, except for some essential limitations of laboratory and technician availability, teams worked at their own pace.

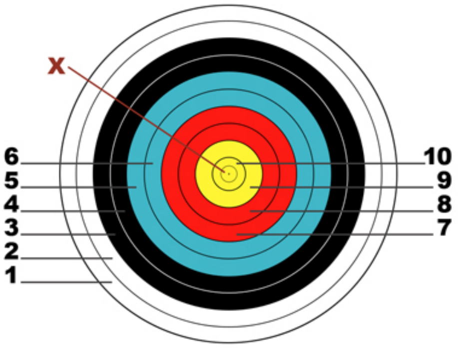

Figure 1: Target with scoring rings.

4.2. Phase 1: modelling the flight of the missile

Students soon realised that achieving a desired range requires control of multiple parameters, not least the mass of the object – that would only be specified on the day of the competition (various different projectile masses would be set) so teams had to make their catapults adjustable to compensate for this if they were to hit the target and score points. Hence, students were required to build a mathematical model to assist with range finding using an Excel spreadsheet and allowing for input of variables such as the missile mass, launch angle the spring constant and the geometry of the catapult design. A single optional lecture provided general support for this activity.
A typical catapult, such as the one shown in figure 2, is a lever ($L_1 + L_2$) pivoting at height, P, and powered by the extension, δ, and force, F, in one or more springs. Although it is possible to analyse this device using Newtonian equations of rotational motion, an energy approach is far simpler and provided a reasonably accurate model of the system.

For this system, the input energy is entirely derived from the spring's elastic potential energy found from $\frac{1}{2}k\delta^2$ where k is the spring constant (the students would need to determine this by experimentation. The stored energy is converted into kinetic energy of the projectile $\frac{1}{2}mv^2$ The gravitational potential energy is given by mgh where h is the height at any point. So the energy in the shot is at any point on the trajectory is $\frac{1}{2}k\,\delta^2 + mgh$

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assuming that all the spring energy has been transferred to the mass on release. On the day of the competition, teams should be able to use their model to quickly determine the release angle, θ necessary to hit the target. The process replicates, in simple terms, how naval artillery is actually targeted.

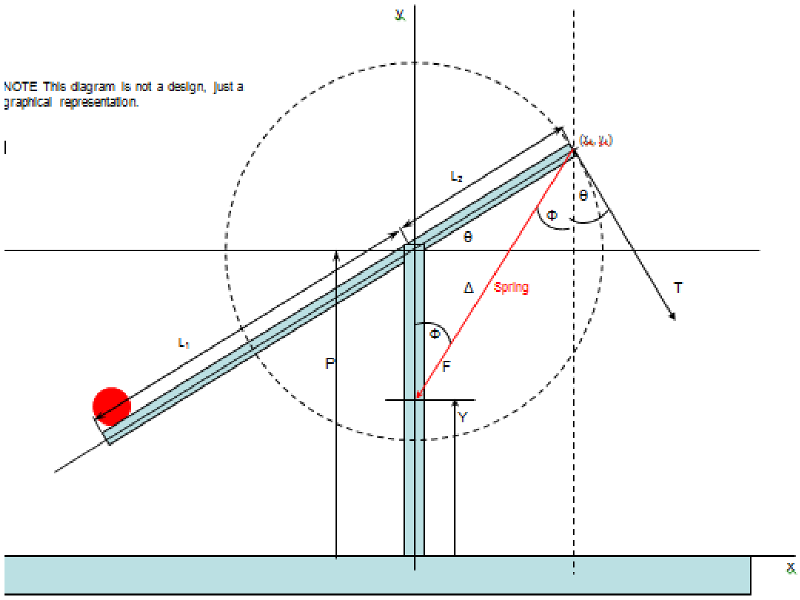

Figure 2: A typical spring powered catapult.

4.3. Phase 2: Catapult Design

Some additional information was needed in parallel with optimizing the design geometry and used to extend the scope of the Excel model at this stage. In particular, students needed to determine the characteristics of the selection of springs supplied. To do this, they were encouraged to visit the strength of materials laboratory, where technicians had been primed to offer just enough assistance.

After only four weeks at university, students have only started to acquire basic 2D CAD skills. The catapult would be made from MDF parts, cut by lasers to their design. Each team was issued with an extension spring, an A3 size sheet of 6mm thick MDF and a 150mm long plain steel pin for a pivot. There would be a fixed baseplate onto which the catapult must be bolted for the competition; this was specified. The actual design was for them to decide.

4.4. Phase 3: Manufacture and assembly:

Teams needed to deliver their completed and checked CAD drawing showing how all the component parts would be cut from a single sheet of MDF to the laser laboratory.

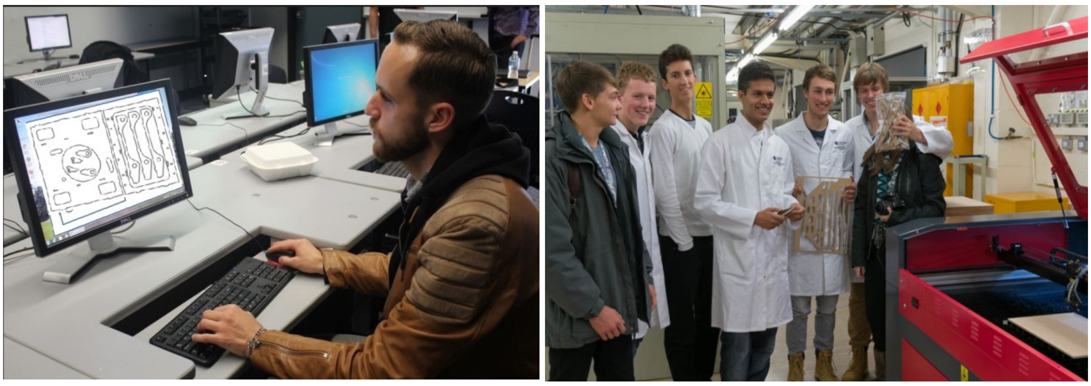

Figure 3. Computer Aided Design and Manufacture.

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Teams took responsibility for booking a ‘manufacturing slot’ as soon as their design was ready. CAD drawings were quickly post-processed into machine control files and students could observe their parts being cut out. It was then up to the teams to construct their catapult, fixing the parts with a suitable adhesive and at this point they would discover just how good their earlier design work had been.

4.5. Phase 4: testing and development

There was plenty of scope for creativity within the design, although in practice, it was clear that most teams followed the lead of the examples shown by the lecturers for the basic configuration. Once they had determined their preferred design, they were required initially to produce a tessellation of the various parts on a single A3 sheet of 5mm square graph paper in preparation for converting this to a CAD file using their newly acquired CAD skills.

Figure 4: Students generally underestimated the time needed for testing and development.

Students quickly learned that translating conceptual and theoretical ideas takes longer than imagined. Typically their attention to detail was lacking, where precision makes all the difference. Two examples of the areas where iterative corrections were almost universally found to be necessary were:-

(i) The 2 dimensional parts needed to be joined together to form the 3 dimensional machine and, unsurprisingly, this required the use of adhesives. However, impatient students would not allow sufficient time for the joints to cure. Worse, some chose to ignore that advice that had been given and simply butt the adjacent parts together. Those who incorporated joints that would be familiar to cabinet makers into their initial designs suffered far less catastrophic failures under the sudden impact of stopping the spring catapult. These details, when incorporated at the design stage actually added no complexity to the manufacture but added significantly to the design integrity and strength.

(ii) First year engineering students are familiar with Hookes’ law ($F = k\delta$) but apparently naïve about its practical application to the helical spring. The exercise provided a useful correction for some although many springs were quickly destroyed by being over-stressed. We learnt to keep a good supply of spares.

4.6. The Competition

On the last day of the week, all teams demonstrated their devices, for both accuracy and distance. They were told to fire two shots each of 15g, 20g, 25g 30g and 35g, 10 in all at the target, and in a separate test, a single 50g shots was used for the distance metric. The students used their Excel model to set their trebuchet for each shot. The machines were also weighed as light-weight was another specified metric for the competition.

The score for each team was calculated according to the following formula, declared at the start:

$$\textbf{Team score} = \alpha A + \beta M + \chi D + \delta L$$

where A = accuracy (sum of scores for 10 shots), M is the relative mass (of the device) score calculated in proportion from the heaviest device to the lightest, (light = best), D is a tutor-judged design score (%) and L is the length of the distance shot in metres; with coefficients; α=0.5, β=0.2, χ=0.2 and d = 0.1. A bonus accuracy mark was added if a projectile landed in the tin can placed in the centre of the target. Final scores varied

between 40% and 81% with a mean of 56.9% and standard deviation (30 teams) of 9.8. Small prizes were awarded to the top three teams.
Staff, who had not been otherwise involved, were invited to attend the test sessions. Some were bemused by the appearance of mayhem but most were immediately converted by the enthusiasm of the students to appreciating the value of the exercise.

Figure 5: Photographs from competition day.

5. Post-Project Student Survey

An online survey was constructed and made available to all participants immediately after the project week to understand to what extent the social and learning objectives had been achieved and also to determine how well the disruption to normal processes had been received.

The student population was 157 with approximately 91% male and 9%, female. The response rate was 57%. 75% of the 28 teams were randomly constructed of 6 members while the remainder had between 4 and 7 students. The response rate for teams (at least 1 member responding) was 96%.

The following is a thematic discussion of the survey results.

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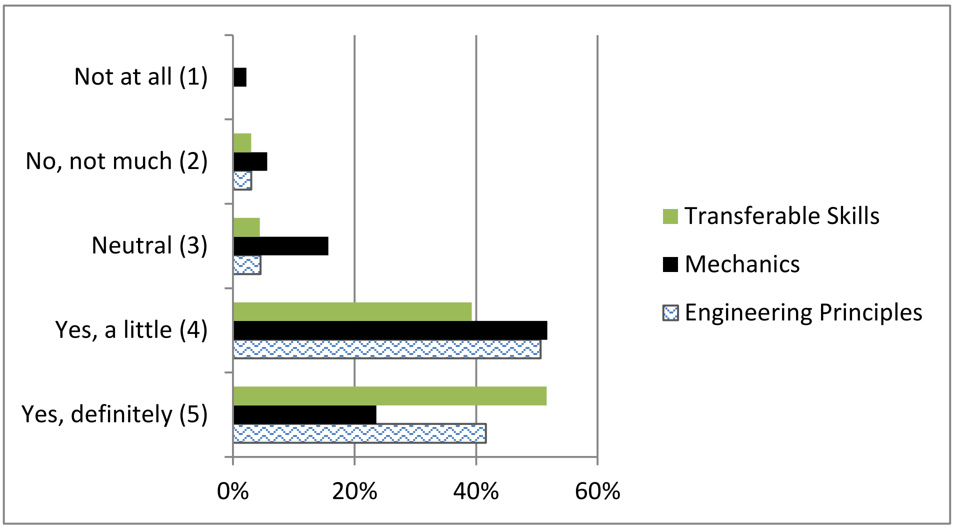
5.1. On Teamwork

Although all teams attempted to plan as they had been encouraged to do so by the staff, there was evidence that this planning had not been universally effective, unsurprisingly suggesting that new students need further development here but also demonstrating that many had identified toe need to do this: only 21% claimed to have made a plan and stuck to it, whereas 51% stated that "their plan developed over time; Others said their plan had been overruled by events (16%) or that they just did what they needed at the time (10%).
Given such freedom, it is not surprising that some within this relatively large cohort will not pull their weight. Asked how many individuals within their team did less than half the team-average man-hours, were regularly absent or failed to deliver tasks, the survey returned that 57% had experienced an even work distribution, 22% had one weak member and the remaining 11% had two or three within their number. The majority claimed to have spent a useful amount of time participating in the project. 64% had been active at some point on all five days and over half had spent between 15 and 25 hours working, and 5% more than that.

5.2. On Learning

Students were asked if the project had enabled them to learn or consolidate knowledge of engineering principles, and mechanics and if it had been effective for improving transferable skills such as researching, communication or IT and rate their perceptions on a simple 5-point Likert scale. There was spectacular agreement in all three sections and the data are compiled in table 1.

Table 1. Perceptions of improved understanding or ability in three aspects.



5.3. On Commitment and Community

Helping students feel engaged with and committed to both the School and the profession was one of the central aims of the project. Education need not be dull or boring and it is well known that humans do their best work in a lively and enjoyable atmosphere. It is therefore, of some concern that engineering coursework can so rarely be described as enjoyable: consider writing the average laboratory report, for example. The results of this survey were different: asked "on the whole, did you enjoy the task?" 90% said yes and of the remainder, 8% were neutral, and this was backed up by the enthusiastic responses to a supplementary free text question asking "what was the best thing about the project". Almost all respondents wrote something and the overwhelming majority talked about things like working together as a team, exercising creativity in an unconstrained environment, seeing a design through to fruition and being allowed to put theory into practice.

The questionnaire went on to compare this method of learning with other more conventional styles and to enquire whether they would have preferred more staff interventions and support but, there was overwhelming support for the status quo. Asked "would you have preferred more formal class sessions in the project?" 75% said no!

On the wider aspects of engineering, and, postulating that a good experience here might encourage better engagement in the more traditional engineering sciences, students were asked if the project had made them more or less interested in Mechanical Engineering: the results were 71% more interested; 27% neutral and 1% less interested.

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6. Conclusions

The obvious enthusiasm derived from work like this is undeniable. External evaluation [8] had already shown that showed that there is a strong consensus regarding the benefits of the module, not only between staff and students, but also with the information on the module feedback forms from previous years, information freely given in the student survey and copious anecdotal evidence. Taking a break from conventional teaching to incorporate team-based project work where staff and students work together in a competitive environment appears to improve relationships and sets students at their ease. The obvious enthusiasm derived from work like this is undeniable. And the reported capacity for learning in three separate aspects is encouraging. More important, students appear to thrive on exercising creativity, and for most, this, coupled with the competitive element is a strong motivator that tends to compensate for other course elements they find less exciting. The authors are confident in having met the intended outcomes.

The catapult project has improved on the original model. In particular, it has introduced a stronger element of engineering science and the application of newly learned CAD skills. An unexpected bonus was the additional learning that surrounded the use of the spring. Many variations on this basic theme Model – design – manufacture – build – test – compete, are undoubtedly possible and could be tailored to any engineering discipline and tuned to whatever level.

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Creation of a Collaborative Study Community in Engineering Studies

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Abstract

This paper describes a novel course structure at the beginning of engineering studies. The aim of the course was to integrate new students into the study community by keeping them tightly together in one classroom during the first eight weeks of studies. The idea was based on project-based learning that has already been introduced at many universities. However, the course did not revolve around one single project, but consisted of several small team assignments. The paper is a case study that describes the course and its findings, comparing the situation with previous years' experiences that have been documented in several earlier studies. Feedback and notes were collected regularly during the course. Student surveys after the course indicated a high student satisfaction.

Keywords: *Engineering education, Collaborative practices, Networked expertise, Project-based learning*

1. Introduction

The traditional, strictly subject-oriented pedagogical approach seems to have come to end of its lifetime. The work-life practises have changed from individual effort to collaborative and team work tasks. This change is reflected in requirements set for university studies where the engineering profession is defined by competences [1][2]. However, institutes for higher education have largely continued to follow content-based curricula where the topics are studied in separate courses.

Dropout rates for engineering degree programmes in Finland have been high for the last 15 years, which has led to a search for more attractive educational methods. Many engineering education institutes have sought to introduce engineering practices through project-based learning into the curriculum. The global CDIO initiative has gathered a number of institutions around a common curriculum structure, including several Finnish universities [3]. On the other hand, project-based learning has been applied by Aalborg University in Denmark as well as many others [4]. CDIO projects and elements have also been included in the Finnish curricula since 2009 [5]. The need to introduce more multidisciplinary projects has been acknowledged, and the Metropolia Minno scheme was developed as a framework for third year innovation projects where students from different disciplines design solutions for real business problems.

Collaborative problem solving and project-based learning have been considered as central methods to educate present day engineering students, because they simulate challenges that the students will face in the professional work, such as open ended assignments, uncertainty and coordination of collaborative efforts [6]. Numerous implementations of project based learning have been reported in various countries in recent years [7- 9].

Gokhale (1995) found that collaborative learning environment provided students with opportunities to analyse, synthesise and evaluate ideas cooperatively, and informal discussions and interactions helped students to understand and share knowledge and experience, get helpful feedback and learn critical thinking [9]. Kreins, Kircher and Jochems (2002) noted that social interactions are the key to an efficient collaborative learning and lack of interactions can prevent collaborative learning [11].

Muukkonen and Lakkala (2009) studied an undergraduate university course where the students were exposed to dealing with open-ended collaborative inquiry. They concluded that dealing with uncertainty and areas beyond one's expertise and engagement in self-directed collaborative work are decisive experiences for developing the needed skills in knowledge work [12]. Moreover, Meier, Spada and Rummel (2002) identified five empirically induced aspects for successful collaborative process: communication, joint information processing, coordination, interpersonal relationship, and motivation [13].

1.1. Aims of the study

Despite various efforts to introduce projects into the curriculum, the main study mode at Metropolia was based on lectures and laboratory exercises until August 2014, when a new university-wide curriculum was introduced. The curriculum reform was based on principles of learning such as knowledge inquiry and collaboration across disciplines in co-operation with enterprises and community [14][15][16]. The head of the international Information Technology programme seized the opportunity to fully change the modes of study, and decided to start the studies with an Orientation course that consisted of various elements introducing students to university studies, projects and teamwork practices.

The aim of this study is to examine how the planning and implementation of the Orientation course took place, and how well it succeeded in creating a collaborative study community. Also, educational methods as well as the course elements and tasks are described. The findings discuss how both the students and teachers experienced the course practices, and how they described the benefits and challenges.

2. Materials and Methods

This paper describes a case study of collaborative repeated practices in one course unit. All exercises in the course contributed to collaborative and repetitive practices. Students completed some individual tasks such as setting up their PCs, installation of home pages and photo-editing, but most assignments were done in teams. The team set-up varied depending on the assignment, but most of the time three to four students worked together.

A particular feature of the course was relative lack of material produced by teachers. Lectures were kept short, and the main aim of the lectures was to introduce a new task. Instructions were as short as possible, and students were encouraged to ask for help and help each other as much as possible. In fact, students produced some of their learning materials in teams. Nevertheless, students were not left alone with hard problems, but one or two of the teachers were always available for instruction.

2.1 Setting and participants

Planning sessions for the Orientation course began in spring 2014. A team of teachers were invited by the head of IT degree programme to plan together an introductory course for the new first year curriculum. The aim of the new curriculum was to integrate smaller courses into larger ones and renew the pedagogical models and habits used at our university. The head’s personal aim was that the IT degree programme could be in the frontier of the pedagogical reform.

The team of teachers had seven planning sessions between March and June 2014. Weekly course schedules were fixed together and proposed for the schedule planner. Discussions about actual project for the IT Orientation course resulted in dividing the project into smaller tasks and having weekly themes. Teachers' notes and comments were collected into the school’s intranet tool and analysed later.

The new pedagogical approach suggested also changes in the facilities. A proposal for investing in new furniture and other facilities was made. Discussion about suitable IT tools and environment as well as evaluation and grading criteria continued until the beginning of the course.

Mathematics and the basics of Finnish language were taught separately, but English communication skills were partially integrated to the project. The practical application of the language and communication skills were linked to the project and they were evaluated by several project teachers during student presentations. The orientation course aimed at giving students a good understanding of the basics of information technology, as well as enhancing independent learning skills and adopting academic practices. When completing course assignments, the students also learned teamwork and project management skills.

The student group consisted of 48 engineering students with a diverse nationality background, the majority being young male Asians from Vietnam and Nepal who arrived in Finland only a few days before the beginning of the semester. They were divided into two study groups, which both had five teachers from different professional disciplines such as mathematics, software, media engineering, and communication skills. Even though students mainly had a high school or secondary school background, several also had previous university studies in their own country.

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Classroom furniture were arranged in groups of small tables that could flexibly be rearranged for teamwork or lectures. In both classroom there were movable white boards, six fixed PC work stations and a teacher's desk with a PC and projector connection. However, the facilities were not in place when the semester started. In fact, students had to assist in setting up and furnishing the classrooms. This was not intended beforehand but a reality that the staff and students faced because of administrative delays. The situation caused some stress to the staff members; however, students rather took it in a positive way. The first study week has always been somewhat disorganized, even in earlier years, because many foreign students arrive late in Finland due to visa processes, and courses cannot start in full when several students are missing.

2.2. The course outline

The course was implemented during the first 8-week-period of autumn semester 2014. The course outline was arranged around weekly themes, each having technical, social, epistemological and cognitive goals.

Before the beginning of the course the new students had a so called orientation week arranged by Metropolia, when they received basic information about studying in Finland and at our university. They also received keys to the classrooms and were given access to different IT systems. Their very first task was to design and implement an egg dropping device that was immediately tested in teams. The only given instruction was that the egg should land safe and sound to the ground. The aim of this task was to work as an ice-breaker and help the students get to know each other. The experiments were video-recorded and shared with students and teachers.

The first week's theme was to get to know one another. The two study groups were instructed slightly differently. In group A the students were asked to work in small teams and make a team presentation on the topic "who are we " in English using digital tools. Group B the students were asked to give individual presentations on the topic "who am I" in Finnish language and using paper only. The same theme was also used in Finnish language classes. The teams and students presented their posters and presentations at the end of the week. Moreover, cross-group interaction took place when international students presented their group to a Finnish group of first-year students, and the Finnish students showed their game project designs to the international students. Consequently, both groups went together to a student association event during the weekend.

The second week's theme was to get to know the university's facilities. The technical goal was to learn documentation skills and to become familiar with Metropolia's IT systems, whereas the social aim was to practice teamwork skills. The systems and facilities were divided within the small teams and each team's task was to find out and document the selected system, facility or service. The material was collected to a shared wiki-page into Metropolia's IT systems, and presented to other teams. One day was spent in installing Linux on student laptops, which they had for their personal use for the first study year. Furthermore, an unscheduled social event, a freshman party, was organized at the end of the week to celebrate the completion of furnishing the classrooms.

Weeks 3 to 6 were arranged in different order between the two groups due to scheduling issues, but the contents were the same.

The third theme was a five-day crash course on assembling a personal computer, aiming to give students a real hands-on experience about how to manage with PCs and operating systems. Another goal was to teach students to work in teams. The first day contained lectures of the history of personal computers and discussions on what should be considered before buying a new computer. The homework was to simulate how and what to buy in case the students should build a computer for their own family member. Learning was based on listening and learning from expert stories. On the second day the students assembled desktop computers from parts. Teams were built around students who had some experience in the building process; their task was to minimise damages to components. The teams installed the most current operating system (MS Windows 8.1) and the whole class discussed how to benefit from the knowledge they learn during this course. The students were encouraged to value the knowledge received as they will certainly need to support their relatives and neighbours when they visit their family back home. During the following days, the students learned about computer viruses, the Internet, built a network by themselves with wireless routers and learned to look under the hood of an operating system. A small competitive task was given at the end of the week: the winner was the team that could first remotely start Notepad on another team's computer.

Tasks during weeks 3 to 6 dealt with basics of photography, photo editing, creating group portfolios and web-pages. The aim was to learn the basics of portrait photography, the properties and formats of digital images, digital image editing, and the basics of HTML and CSS coding. Each student visited a photography studio and practiced taking portrait photographs in small teams and used the material to create their own web-page portfolios. All learning and processing took place in small teams within the group. Team work methods and best practices were introduced parallel to these exercises.

Weeks 7 and 8 were reserved for feedback, final evaluation and supplementary work. The students were guided to complete all unfinished assignments and feedback was given before the final evaluation. Separate examinations were arranged in mathematics and Finnish language. In English communication, the final homework was to find a job advertisement in the field of IT that they could consider applying for and write a CV and cover letter for that. The English communication teacher was also present when students were presenting their project works and evaluated the presentations together with students and other teachers. The final evaluation was made together with all teachers involved in teaching and the final grade was discussed before it was revealed to the student. The last week was reserved for supplementary assignments in order to get the students who had arrived late on the same page with the rest of the class.

2.3 Data collection and analysis

This case study relies on notes during the planning phase, teacher observations, materials created by the students, feedback collected during and after the course, and the course results. The observations of classroom practices were recorded to field notes by one teacher of the course. Teacher observations and produced materials were used to descriptively evaluate the course practices.

Students' and teachers' opinions and experiences on the course were collected with the help an online questionnaire after the course. The following student questions were used as data: How would you characterize your overall experience in the course? What has been positive or impressive in the course? What has been challenging or disturbing in the course? Teachers answered to the following questions after the course: What succeeded in the course? What did not succeed well? How were the goals of the course achieved? What would you do differently if the course was implemented again? In all, 32 students and five teachers answered to the questionnaire. The written answers were analysed in order to unfold the students' and teachers' experiences and opinions of the course practices and the teachers' evaluation of collegial collaboration when planning and implementing the course. Descriptive summaries of the answers were constructed in a data-driven manner.

Even though the course included a wide variety of subjects, a single grade was given for the whole course. Numerical evaluation on a scale from 0 to 5 for each task was used in grading. When evaluating how students had documented the information about the university's facilities on wiki pages, also peer evaluations were collected and used. Finally, task evaluations and mathematics as well as Finnish language grades were assessed according to their relative work amount when calculating the grade for the whole course.

3. Findings

3.1 Observations

The first assignment was a team presentation "who we are?" that was done to get the students to know one another learn about each other's backgrounds. One group collected the answers in a poster, while the other group created a PowerPoint presentation. The other larger task was to create wiki-pages that explained the learning environment in the campus including sports and library services as well as the intranet and IT services. The students wrote a description of themselves also in the Finnish language that they had just started to learn. Embedding language studies to other professional activities motivated students in their language studies, and the learning results were better than in the past. Moreover, collaboration between subjects encouraged students to complete tasks on time, not to mention effects of peer pressure in the delivery of assignments.

Story-telling and dialogue in the classroom about real incidents related to computer installations turned out to be an amusing episode that the students remembered well. It also triggered a lively discussion where students could learn from their classmates' experiences and knowledge. Going over team borders turned out to be rewarding. Team work across teams was the real highlight of creating collaboration. Teams had mostly worked as separate groups only concentrating to internal communication but eventually they created a network where the computers communicated over the team borders.

A major, and rather surprising finding of the course was the fast speed of adopting basic teamwork practices even though most of the students had never before been allowed to work in teams at school. Probably a tight study group helped immigrant students adapt to the new country and study environment, and made them feel more confident and secure in the new environment.

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Another important finding was the high degree of independence that the student group acquired within a few weeks. One of the first tasks was to setup a personal laptop by installing Ubuntu Linux, browsers, and office software on it. This task was completed within a few hours, with remarkably little teacher intervention, as more experienced students took the responsibility of assisting less experienced users. That pattern was adopted as a permanent study mode, and it gave a good lesson for instructors, as well. The teachers had to acknowledge that students have previous knowledge and skills that they were able to use creatively when assignments were structured in an open way.

3.2 Students' evaluation of the course

When the students were asked to evaluate and give feedback about the course, the results were quite positive. 21 students stated that because of the course they were "more familiar with the study environment", "able to manage timetables effectively", "studying had been interesting and practical" and ending to the praise such as "great", "fantastic", "wonderful" or "the best orientation course I have ever had".

Four of the students experienced the course neutrally commenting it to be satisfied, quite satisfied, or "what I expected" Only one student complained that he/she did not learn very much or that the course was trivial.

When asked about the positive or impressive aspects in the course, the most frequently mentioned aspects were interaction in general, receiving and giving feedback (5), getting to know the classmates (6), teachers' help and guidance (6) and teamwork (5), as well as learning general knowledge and new technologies (5). Also, the schedule or rhythm of studying (5) were appreciated. Some students also mentioned the overall arrangements (3), that everything was good (3) or the facilities were nice (2). Overall (3) the students liked the arrangement and thought that everything (3) was good. Also, good facilities were mentioned twice.

To the question about challenging or disturbing issues, some students commented having no problems or wrote that everything was ok (4). Some students (3) had experienced that the course structure and content had been unclear, one student complained about unknown evaluation criteria (1) and lack of illustrations (1). Group work was mentioned once as a negative thing (1). Giving a group presentation was "unfamiliar" for the student (1). Languages, specially the Finnish language (3) were also mentioned as challenging. A couple of students complained that the exercises were trivial, or there were too few practices, or the materials or end products were not practicable. The schedule, early wakeup times and sleepiness were each mentioned once. Some observations about weak basic IT knowledge and difficulties or confusion with technical practices like CSS/HTML coding or using Ubuntu and GIMP were mentioned.

3.3. Teachers' evaluation of the collaborative planning and course practices

Teachers answered four different questions that are summarized here. To the question about what worked well in the course, the issues mentioned by several of the five teachers were teacher collaboration in integrating teaching (3), schedule and arrangements (3) and communication with students (3). Also, active and motivated students (2), student learning (1) and teaching in general (1) were mentioned in the teachers' answers as positive.

Four teachers answered to the question about what did not work well in the course. Two teachers mentioned that the course had a tight timetable. One teacher complained about difficulties to find time for the teachers' joint meetings, and one teacher mentioned that not all subjects integrated naturally into the same entity. One teacher was dissatisfied with the classroom facilities. One teacher mentioned that transfer students who had already studied in some other programme did not adopt new working methods very easily; they were also simultaneously conducting second-year studies.

All five teachers evaluated that the goals of the course were achieved well. One teacher thought that the goals were exceeded because the competence level of the students was so high. One teacher mentioned that the students' motivation for learning increased from the beginning. One teacher remarked that even though the goals were met, more time should have been allocated to practicing the new ways of learning.

The teachers were also asked, what they would do differently in a new implementation of the course; four teachers answered to the question. One teacher would decrease the amount of content, and one would organize mathematics as a separate study unit. One teacher thought that not so many teachers need to be present in the class at the same time. One teacher discussed about the role of the transfer students; there should be either first or second year students, and no other options should be offered.

3.4. Pass rate of the course

In total 48 students started in the Orientation course and of those, 47, or 98% passed. This represents a very high pass rate, although exact comparison with earlier years is somewhat complicated because of different course structure.

4. Discussion and conclusions

Collaborative work towards a shared goal has proven to be an efficient and inspiring mode of study, and in this case, it was introduced immediately from day one. The aim was to create a community of first-year students who would later support each other in their studies.

One of the main problems with international study groups has been the slow integration to the new university environment and adoption of proper study habits [17]. The students have sought help from teachers and study advisors, requiring repeated instruction about the same issues. The orientation course enabled students to acquire basic knowledge of the study environment together, and after learning to know each other, they had a large pool of informants available. The course also helped students to make friends, because everyone was forced to work with others. The collaborative practices developed during this Orientation course can later be observed when the students proceed with their studies at Metropolia. Whether the team work and collaboration skills will persist during the second academic year, remains to be seen.

Teams must be encouraged to work as a team by designing tasks that clearly benefit from team activity. Students should be encouraged to present their own opinions and make them see their own capabilities and potential. Also, it is important that they are encouraged to help other team mates and classmates in professional matters. Cross-team competition and mutual helping between teams simulates professional situations within companies or with clients.

In educational settings when applying collaborative practices, students do not necessarily succeed very well in group work or progress expectedly in finalizing their products [18][19]. One reason for this is that students are left too much alone in managing the new ways of working; they have to learn the critical skills spontaneously or through trial and error. In the present case, through multiple successive group assignments the students got repeated opportunities to practice collaboration skills as well as get feedback from peers and guidance from teachers, which were mentioned by many students as central positive aspects of the course experience.

The findings are not surprising when compared with other results of project-based learning [7][8]. However, the faculty at our university has been reluctant to apply collaborative methods due to the lack of convincing information. Therefore, close follow-up and continuing research of the development of student competences is still needed. Nevertheless, the most important goal from the university point of view was achieved: for the first time all but one student passed their first period courses.

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Students' perceptions on collaborative work in introductory programming course

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Abstract

Pair programming and other forms of collaboration are generally considered useful for learning. Still, as educators and researchers, we should also pay attention to students' opinions on the collaboration and the effects it may have on the quality of their work. While redesigning an introductory programming course in our institute we converted half of the lectures into automatically assessed interactive tutorials with heterogeneous set of exercises. Students completed the tutorials in collaboration, with two students working on one computer.

In this paper we first present the pedagogic background for making the aforementioned redesign choice. Next, the technical implementation of the tutorials and pair work is described. At the end of the course, a comprehensive survey was given to students (N = 153), asking them to describe whether they preferred collaborative work over working alone, how effective they found the collaborative work, and what kind of factors they think influence the effectiveness of working with peers. Based on the results, students generally were in favor of the collaborative work and in their opinion the greatest benefits of pair work were the knowledge sharing, improved learning, faster problem solving and learning interaction skills.

Keywords: *Collaborative learning, Pair programming, Student feedback, Programming Education*.

1. Introduction

The effects of collaboration on learning has been studied in various ways in various fields of study and collaboration in general is thought to be beneficial for learning. In programming education the collaborative technique of pair programming [1] originating from the world of professional programmers has been widely studied and found to be effective. Our earlier studies also show that collaboration has improved the learning of basic programming skills and at least it hasn't negatively affected the learning results [2] [3]. However, even if the learning results are positive, do the students find the collaborative work to be helpful and efficient? Do they like to work collaboratively?

The results of collaborative work reported in this paper are from a survey given in an introductory programming course. We wanted to find out how students feel about working collaboratively with other students. The introductory programming course included weekly tutorial sessions where students worked in pairs with one computer. The collaborative technique used in answering to the assignments in the tutorials was pair programming, where one student is the driver who writes the code and the other one the observer who reviews the code while it is written. The roles of the pairs are changed from time to time to evenly expose students to the different methods of working. Although the pairs were to solve the problems mostly together, they could also discuss them with other pairs. So in addition to the pair work, there was another level of collaboration going on during the tutorials.

In this paper we first present other studies related to the subject and what kind of contribution this will introduce to this field. We then describe the introductory programming course where the study was conducted, and more precisely the collaborative work setup utilized in the course. Thirdly, a short description of the learning platform used in providing the various automatically assessed programming assignments is presented. Section 4 describes the survey given to the students and report the results of the survey. Finally, we discuss the results and present some conclusions.

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2. Related work

There are several methods and approaches of pedagogy that emphasize collaboration in learning including active learning [4], problem based learning [5] and computer supported collaborative learning [6]. The collaborative setup presented in this paper includes aspects from all of these approaches. Additionally, all the three types of interaction presented by Moore [7] are present: The pairs working with the programming problems (learner-leaner), the mentors helping the pairs (instructor-learner) and the collaborative learning platform providing automatic assessment and immediate feedback (learner-content).

Pair programming has been shown to be effective way to learn introductory programming by several studies. Nagappan et al. [8] report a study about pair programming and conclude that the pair programmers performed better in projects and exams and were more likely to achieve at least the average grade from the course than the solo programmers. Additionally, according to a survey most of the students were looking forward to working in pairs also in the future. McDowell et al. [9] studied the effects of pair-programming in an introductory course where data was collected from total of 600 hundred students. They found out that students who did programming assignments in pairs produced better programs, had higher course completion rates and performed as well as the solo programmers in the final exam. Another study [10] reports that pair-programming improves course pass rates and contributes to students continuing in computer science related majors. Additionally, it concludes that students were more likely to pass the following programming course where programming was done alone. Students also produced higher quality programs, were more confident in their work and enjoyed answering to programming assignments more than the solo programmers.

Various algorithm and program visualization tools have been utilized in teaching computer science during recent history [11]-[14]. Also the effect of student collaboration on learning CS subjects with such tools have been studied. For example the effect of student engagement on collaboratively learning algorithms and data structures with an algorithm visualization tool called TRAKLA2 was reported in [15].

3. Tutorials

The collaborative work study was done in university level introductory programming course. The course is the first programming course for all students in our institution. Almost 200 hundred students attended the course. Last two instances of the course have been redesigned to include collaborative work. One weekly lecture instance was removed and after that each week of the course included one two-hour lecture and one two-hour tutorial session. Additionally, there was four demonstration sessions where students were given programming tasks a week before the sessions and they had to solve the tasks before the demonstrations. The two-hour tutorials were held in a large lecture hall where students brought their own laptops. The lecture hall has a wired network and power outlets for almost 100 computers. As the students worked in pairs with one computer during the tutorials, this was sufficient for the little under 200 students attending the course.

For each week's session a tutorial was prepared in the collaborative learning platform used (see section 4). The tutorial consisted of some learning material, including text, images, tables, videos, etc. and automatically assessed assignments. Basically, the topics from the same week's lecture were added as material and divided into sections, and for each section various amount of automatically assessed assignments were added to rehearse the topics and measure the learning. The measuring is useful for both the students and teachers as the student gets immediate feedback on how he has understood the topic and teacher can see from statistical views of the platform how the students are progressing.

There was no control on how the pairs should be formed during the tutorials. Only, at the beginning of the course we helped in finding a pair if there was some people left without one. The students were also encouraged to discuss and ask for help from each other and other pairs as much as required. Additionally, there was also few mentors (older students) attending each session, and if a pair got stuck with some problem and couldn't get help from another pair, they could ask one of the mentors to help them.

Students had to attend at least five of the seven tutorials in the course and solve at least half of the assignments in the tutorials. Each tutorial was open for a week after the tutorial sessions, so the students could also try to finish the assignments afterwards. The observed atmosphere of the tutorials was very positive. Lots of discussion was going on all the time and actually there was always pairs that didn't want to stop working and had to be told to leave the lecture hall because the next lecture was beginning.

4. ViLLE – Collaborative learning tool

A collaborative learning platform called ViLLE was utilized throughout the programming course. The VILLE platform provides various types of automatically assessed exercises for various subjects. Additionally, it has quite extensive tools for course management. Basically all tasks during the programming course were provided in the ViLLE platform. Student lecture attendances and demonstration assignments done were stored there during the course. All lecture feedback surveys, weekly assignments and the final exam were also answered in the platform. Still, the most use of the platform by the students was done during the weekly two-hour tutorials. More information about ViLLE can be found in [16].

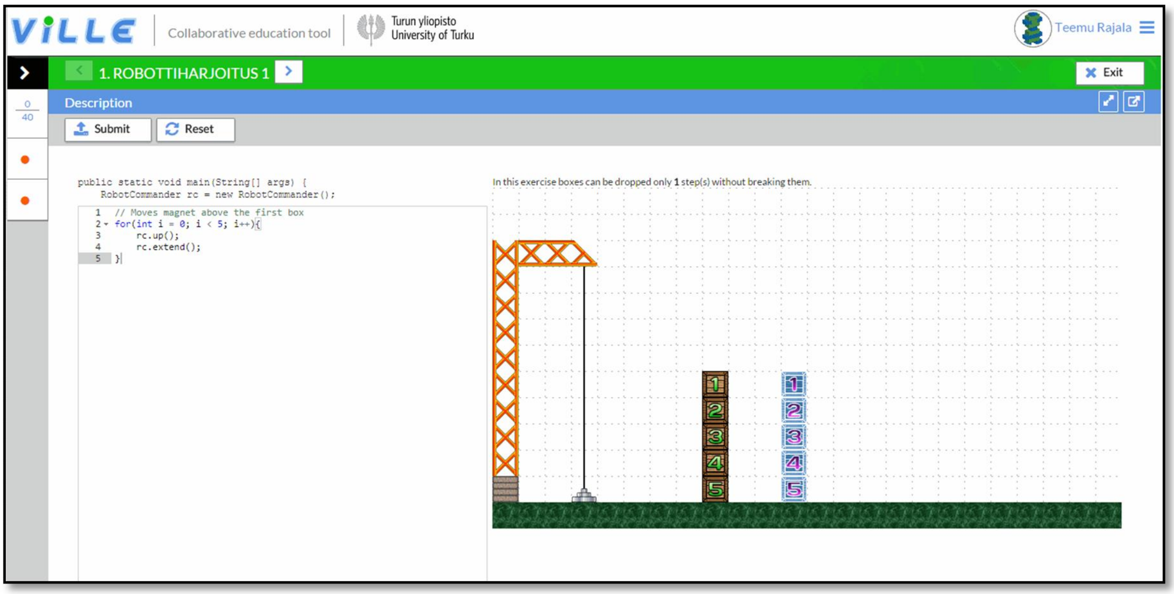

Figure 1. One of the programming assignment types in ViLLE platform

5. The collaborative work survey

The survey was given to students after all the tutorial sessions in the course were held. The learning platform was also utilized in providing the survey to the students. In the survey we asked the students with how many different collaborators they had worked in the tutorials and how they felt about the pair work during the tutorials. Additionally we wanted to find out what in students' opinion were the most beneficial aspects of working collaboratively. Some beneficial aspects were given pre-defined in the survey, but students could also give open answers to the question. Total of 153 students answered to the survey.

Table 1 includes the results from six question from the survey on how the students felt about various aspects of pair work. The answers were given in scale of 1 to 5.

Table 1. Students' opinions on pair work (scale 1 – 5)

Question	Average
Which method is better for the tutorials: working alone (1) or in collaboration (5)?	3.67
Which one is more effective: working alone (1) or with a pair (5)?	3.50
How much did the personality of the pair affect the learning results?	3.94
What do think is your skill level in programming compared to your pairs?	3.08
In your experience, did the pair work improve your learning results?	3.33
Did the pair work improve the quality of the program code produced?	3.33

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Based on the results, the students had the strongest opinion about the effect of the pair's personality to learning results (avg. 3.97). To the question about their programming skill compared to the pair's, the students estimated the skill level to be the same in average (avg. 3.08). This is not a surprise as naturally some of the students are little better and others less and the pairs were not formed based on their programming skill but quite randomly. They also found the method of working in pairs to be more suitable for the tutorials than working alone (avg. 3.67). On the whole the average figures lean towards the pair work.

As seen in table 2, most of the students worked at least with two different collaborators during the tutorials. So the students did not just stick with the pair selected in the first session or with a friend, but actually most of them got to know at least couple of new people. This was also mentioned as a positive aspect of the pair work in several feedbacks given by the students.

Table 2. The number of different collaborators during the tutorials

Number of different pairs	Number of answers (N = 153)
1	39
2	26
3	35
> 3	53

The selection list about the benefits of collaborative work at the end of the survey included pre-defined items including better quality of program code, faster time to solve the problems, better learning, perseverance in solving the problems, knowledge sharing, and learning interaction skills. At the end of the list there was also an open answer field where students could write their own thoughts about the advantages and disadvantages of collaborative work in tutorials. As seen in table 3, almost all students (140) found the knowledge sharing to be a beneficial aspect in collaborative work. Faster problem solving, better learning and learning interaction skills were found to be beneficial by over half of the students. Better program code quality and better perseverance in solving the problems weren't seen as much of an advantage in collaborative work.

Table 3. The benefits of collaboration selected by the students

Benefits of collaboration	Number of answers (N = 153)
Improved program code quality	44
Faster problem solving	99
Improved learning	97
Improved perseverance in finishing the problems	57
Knowledge sharing	140
Interaction skills	90

On the open answer field, most of the comments about the benefits were about the interaction with other students. The students felt that the forced collaboration was a good way to meet new people. Another thing mentioned several times was the benefit of sharing knowledge. Some disadvantages seen by the students were sometimes the large knowledge gap between the pairs. Then the more skilled student had to spend lots of time explaining the programming problems and solutions and the less skilled one couldn't keep up with the pace and probably in some situations just settled for observing the problems being solved. Still, some students with greater knowledge on programming mentioned that helping others to understand was quite rewarding.

6. Discussion

On average, the students didn't have strong opinions against or towards the collaborative work during tutorials. The average of 1 to 5 scale answers were all quite close to 3. This is quite understandable, as the benefits of pair work (programming) can be quite hard to see during the process and on average students didn't have much experience in pair programming before the course. Still, all the average figures are in favor of collaboration. The course results show that after the tutorials were introduced to the course, the learning results improved significantly. There might be also some other factors influencing the results, but we think the tutorials and practical, and collaborative work played a significant role.

The higher code quality in introductory programming courses might not be seen as a large benefit, as in most of the assignments students only write short pieces of code including only few selection statements and loops. Also the improved perseverance in finishing the problems wasn't seen as a benefit by most of the students. One reason for this might be that the tutorial sessions only lasted for two hours and students had to attend them. This might be more important factor in pair programming or other collaborative work that lasts for longer and doesn't have such strict time limits.

It is understandable that the positive effect of collaborative can't be seen by all students. There might be large difference between the skills of the individuals in a pair. Still, in such situations the learning might be improved, as the weaker pair gets help from the better one and the stronger one might be able to better understand the problems as he tries to explain them to the other student. The amount of practical work required from the students also increased after the tutorials were introduced, so that should be also one reason for the improved learning results. Finally, most of the students agreed that the learning results were better, problems could be solved faster and that they learned interaction skills because of the collaborative work. We are especially enthusiastic that the knowledge sharing and learning interaction skills were seen as benefits of the collaborative tutorials by most of the student as those two belong to the soft skills that we here in our institution emphasize and want our students acquire during their studies.

7. Conclusions

The results from the survey show that students had a slightly positive attitude towards the pair work after participating to the introductory programming course. Also, they agreed with some of the pre-given benefits of collaborative work listed in the survey, especially the knowledge sharing. Although the attitudes towards collaboration are not extremely positive, the results from the course after the redesign of changing one of the weekly lectures to tutorials done in collaboration with another student seem to have significant positive effect on student learning in the course. The final exam in the course was at least as difficult as the one before the collaborative tutorials were introduced and there was a significant increase in the pass rates. In future we will continue developing the collaborative learning methods and facilities in our institution. Collaborative tutorials will be and already have been introduced in several other of our introductory courses.

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Interactive Virtual Laboratory, Game-Design Style

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Abstract

Due to budgetary and time constraints, the materials science basic course for non-majors is offered at many institutions in the format of lecture only. In order to enhance the learning experience of the students, an interactive virtual lab was developed to enable the students to have a hands-on practice to complement the lecture. Traditionally, laboratory instruments that are too expensive and, at times, hazardous (such as X-ray diffraction), were unavailable for educating most engineering students. In the current project, funded by Hewlett-Packard and NSF, simulations that use game-design approach, were made the experiments broadly available to large classes. To make the lab even more affordable, it was developed to run on simple laptops. It is widely and freely distributed around the globe. Assessment of the virtual laboratories has been conducted at several institutions in the US and abroad. It included diverse populations in a variety of universities and community colleges with positive results from both learning outcome and student attitude. The laboratories also proved to be successful for demonstrations and hands-on recruiting events for middle and high school students.

Keywords: *Computer game, Hands-on, Simulations, Virtual laboratory*.

1. Introduction

It is well established [1] that students learn best when they are active, able to accumulate and analyse data and draw conclusions. However, budgetary and time constraint have led to a situation when many, if not most, engineering school offer their sophomore classes as lecture only. This is critical because this level (sophomore) is when large numbers of students drop out of engineering majors.

It is very important to both help students grasp the material better and make the learning experience attractive. Our virtual laboratory project comes to satisfy both. The virtual laboratories require less time, money and fit the style of the millennial generation that grew up with computer applications for education, entertainment, and everyday life. Accordingly, the labs are designed to be educational and at the same time attractive. They are also designed for broad dissemination and have been provided to over 40 institutions world-wide.

2. Virtual Laboratory Design and Development

2.1. Development Team

The lab was designed and built using a true multi-disciplinary approach. In fact, not only was the team made of different disciplines, but it also included members from different types of institutions (such as universities and community colleges) and participants from different education levels (from high-school students to university professors). It made it possible to get different perspectives into the design process. World-wide users provided feedback that was used to further improve the laboratories and view from different cultures perspective.

2.2. Principles Used in Developing the Virtual Laboratory

Some of the principles used in the laboratory development include building a virtual experience that will mimic experiments in the physical laboratory to the largest extent possible while keeping the simulation attractive, interactive, and fun.

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2.3. Tensile Test Virtual Laboratory

One example of the development process of the virtual laboratory is the tensile test. Tensile properties are critical for materials application in many engineering discipline, so this was one of nine virtual experiments that are in high demand.

First step was the design of the physical experiment. Engineering materials representing different groups (e.g. ferrous alloys, non-ferrous alloys and polymers) were selected, and samples were made using ASTM standards for shape and size. The samples were then tested, using the appropriate ASTM standards for tensile testing and data were collected. Digital output from the tensile tester was incorporated into the simulation (see Fig. 1), where the load vs. displacement graph is shown. The simulation output includes the numerical values to be used in calculating the stress-strain curve, elastic modulus, yield strength, and ultimate stress. Another output is a video of the sample being strained.

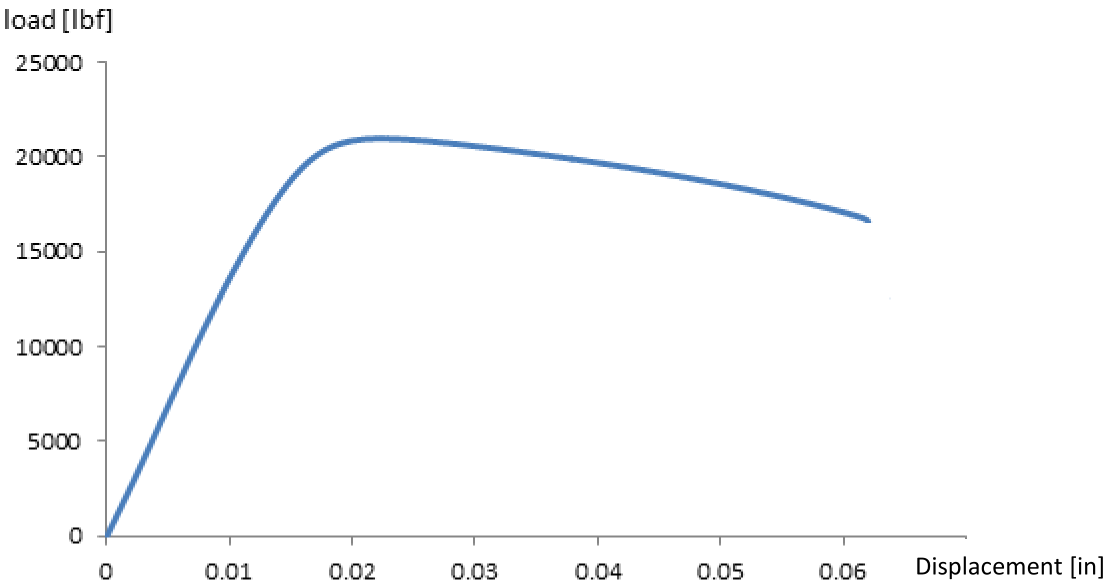

Figure 1. An example of tensile test output in a graph format (Load vs. Displacement); the simulation provide digital values to be used for calculations and data analysis

The tensile tester simulation started with the creation of a realistic 3D model of the tester, sample, furniture and environment. These models were made using Adobe Photoshop and 3ds Max (formerly 3D Studio Max, a professional 3D computer graphics program) [2], the models were them imported into EON reality, an interactive 3D software. EON Studio is a state-of-the-art VR development tool [3]. In addition, some necessary scripts were programmed using C# and JavaScript. The video of the sample being tested (and eventually broken) and the developing graph were incorporated into LabVIEW [4]. Fig. 2 shows a view of the experiment.

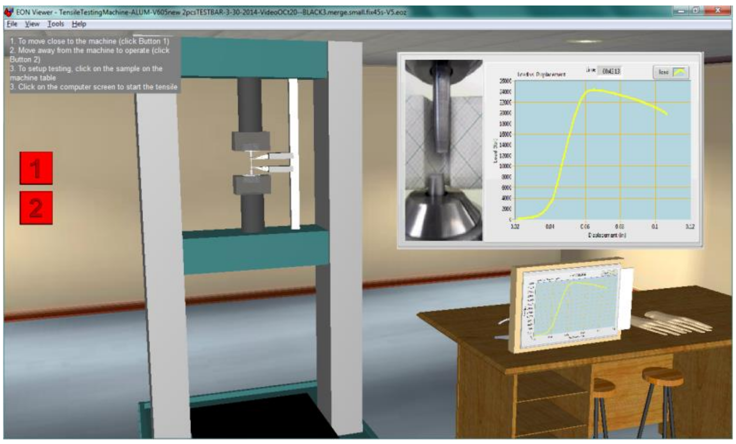

Figure 2. Tensile testing simulation using EON. The machine, sample, and graph, are all synchronized. The inset shown was developed using a video of the physical experiment imported into LabVIEW [5]

The experiment starts with some theoretical background and instructions for running the experiment. It is concise but informative, sufficient to run the experiments and analyse the data without attempting to become a substitute to the relevant lecture.

3. Running a Tensile Test Simulation

After the student has read the theory and instruction provided for the experiments, the simulation is launched automatically. The student then needs to ‘wear’ safety goggles to continue and to choose one sample to start. Following the instructions leads the student to the start of the actual test. The digital data for each sample is only available at the end of the test (no shortcuts!). The student saves the data into a thumb drive, and moves to test the next sample.

The samples’ dimensions are provided as part of the experiment, so upon completion of the test all the information needed to analyze the results is available. The student needs to create a stress-strain curve and use it to determine the main mechanical properties of the material. See an example in Table 1.

Table 1. An example of data analysis of a tensile test results in the virtual laboratory

Sample	Aluminum 6061 T-6	Steel 1045	Steel 4140
Young's Modulus			
Yield Strength			
Tensile Strength			
Modulus of Resilience			
% Elongation @ fracture			
Work hardening (n)			
Toughness			

The last step is the report. This is an important component, and the student is given instructions in regards to expectations, including style.

4. Assessment

We have conducted assessment throughout the development phase in order to improve the developed modules through an iterative process. We have assessment data from different groups. Feedback from users was also used in the constant improvement process. Assessment data included knowledge quizzes before and after the performing the lab, attitude survey, and the grading of lab report (see Fig. 3). All these tools have been used as part of the continuous improvement process.

Comparisons were made between groups of students that (a) used the virtual laboratory as an augmentation to a physical lab, (b) used the virtual laboratory as a substitute to a physical lab, (c) had physical laboratory experience only, (d) had no laboratory experience at all. The assessment data we have collected so far indicates significant positive impact on student learning with achievements that compare well with other groups. More comprehensive assessment data will be collected and analysed in the near future.

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	1 Beginning or incomplete	2 Developing	3 Accomplished	4 Exemplary	Score
Abstract/Summary	Several major aspects of the experiment are missing, student displays a lack of understanding about how to write an abstract	Abstract misses one or more major aspects of carrying out the experiment or the results	Abstract references most of the major aspects of the experiment, some minor details are missing	Abstract contains reference to all major aspects of carrying out the experiment and the results, well-written	
Introduction	Very little background information provided or information is incorrect	Some introductory information, but still missing some major points	Introduction is nearly complete, missing some minor points	Introduction complete and well-written; provides all necessary background principles for the experiment and figures are used for illustration. Sources are referred to correctly.	
Experimental procedure	Missing several important experimental details or not written in paragraph format	Written in paragraph format, still missing some important experimental details	Written in paragraph format, important experimental details are covered, some minor details missing	Well-written in paragraph format, all experimental details are covered and figures are used for illustration.	
Results: data, figure, graphs, tables,etc	Figures, graphs, tables contain errors or are poorly constructed, have missing tiltes, captions or numbers, units missing or incorrect, etc.	Most figures, graphs, table OK, some still missing some important or required features	All figures, graphs, tables are correctly drawn, but some have minor problems or could still be improved	All figures, graphs, tables are correctly drawn, are numbered and contain titles/captions	
Discussion	Very incomplete or incorrect interpretation of trends and comparison of data indicating a lack of understanding of results	Some of the results have been correctly interpreted and discussed; partial but incomplete understanding of results is still evident	Almost all of the results have been correctly interpreted and discussed, only minor improvements are needed	All important trends and data comparisions have been interpreted correctly and discussed, good understanding of results is conveyed	
Conclusions	Conclusions missing or missing the important points	Conclusions regarding major points are drawn, but many are misstated, indicating a lack of understanding	All important conclusions have been drawn, could be better stated	All important conclusions have been clearly made, student shows good understanding	
Spelling, grammar, sentence structure	Frequent grammar and/or spelling errors, writing style is rough and immature	Occasional grammar/spelling errors, generally readable with some rough spots in writing style	Less than 3 grammar/spelling errors, mature, readable style	All grammar/spelling correct and very well-written	
Appearance and formatting	Sections out of order, too much handwritten copy, sloppy formatting	Sections in order, contains the minimum allowable amount of handwritten copy, formatting is rough but readable	All sections in order, formatting generally good but could still be improved	All sections in order, well-formatted, very readable	

Figure 3. Rubric used for grading the laboratory reports and providing feedback to students

5. Dissemination

The virtual laboratory has been developed with a stated goal of broad dissemination. So far, over 40 institutions world-wide have received the developed modules. They are available for download free of charge. The laboratories have been used successfully by a wide-range of ages (Fig. 4).

Figure 4. Students at all ages have been enjoying the laboratory experience

6. Conclusion

In conclusion, the virtual laboratory we have developed that currently includes nine experiments, have proven successful in contributing to student learning and sparking interest in engineering. A systematic and comprehensive assessment is needed to fully appreciate its contribution to students' success. That is planned for Fall 2015.

As Felder and Silverman [6] conclude, "the virtual laboratory is used as an alternative mechanism for achieving the same learning outcomes as in the corresponding physical laboratory." Our experience so far, demonstrates that this goal was achieved using the virtual laboratory.

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Enhancing Freshman Engineering Instruction with In-Class Interaction Systems and e-Books

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Abstract

Electrical engineering students in our department take a year-long series of courses which introduces electrical engineering as a discipline and provides good grounding in engineering problem solving and programing. We have recently attempted to make the second course in the sequence more engaging by applying active learning techniques, including assigned reading and exercises prior to lectures, in-class exercises using a classroom interaction system, and programming exercises during lectures. Our results are mixed: while we think that students have learned more than if we had not used these techniques, we have not completely won over our students. While using an e-book was valuable, we believe that exercises within the e-book were not sufficient and their combination with in-class exercises did not provide sufficient training for students to feel comfortable with the programming. In terms of student problem solving skills, we continue to be puzzled by their difficulties despite their already quite extensive math background. There are also uncertainties with respect to our students' preparedness to take larger responsibility for their education as evidenced by their comments and the fact that reminders were required to keep students doing their assigned preparation work.

Keywords: *freshman engineering, flipped classroom, programming.*

1. Introduction

Our university's first year electrical engineering sequence includes two courses that involve programming and hardware interfacing. Both are taught within the electrical and computer engineering (ECE) department. The first requires the student to solve engineering problems using MATLAB. The follow-on course introduces the C language. One interesting feature of the sequence is the use of MATLAB as a programming environment and introduction to C, in addition to its usual role as a problem-solving tool. To make it less abstract and to establish a real-life connection, we also use MATLAB for interfacing with a data acquisition device called LabJack. MATLAB scripts to control the LabJack can be written in the standard MATLAB environment.

This environment has enabled students to participate in some interesting hands-on projects that combine problem-solving, programming, and interfacing. Historically, student participation in the course consisted of attending lectures, three laboratory exercises related to LabJack and MATLAB interfacing, and participation in team-based projects. We recently decided to increase student involvement, especially during lecture time, because current educational research supports the idea that active learning and active student participation lead to better learning [1,2]. We have modified the course to increase student participation by requiring that: a) MATLAB reading and exercises be done in advance of the lecture time, b) students utilize an in-class interaction system from Learning Catalytics (LC), and c) students use MATLAB on their laptops for in-class exercises. We have also hoped that these changes would result in better attainment of course outcomes, such as improved problem solving or programming skills. In the following sections we will discuss the details of implementation and initial assessment of the effect of these changes.

2. Existing Course Overview

Prior to 2010, our electrical engineering (EE) program's first year experience was provided by a pair of general engineering courses that gave a conventional introduction to engineering analysis and computer programming. Based on feedback from industry partners, alumni, and students, we replaced the original courses with EE-specific versions to emphasize electrical engineering and computing topics and to increase student motivation and engagement. More detailed reasons and background for these curriculum changes were reported in [3,4]. The subject matter from the original two courses was expanded into three new courses: ECE 101 Exploring Electrical Engineering, ECE 102 Engineering Computation, and ECE 103 Engineering Programming. ECE 101 introduces incoming students to the electrical engineering field, its many applications in society, and possible career opportunities. The analysis material was transferred to ECE 102, with most non-EE topics removed to

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make time for more EE focused material. ECE 103 took on the role of teaching intermediate-level programming in C. Surveys from industry and former students made it clear that the single programming course required of EE students was not meeting the expectations of prospective employers. So, it was decided that ECE 102 would expand the MATLAB portion of the course to include general programming in addition to covering its calculation and graphing tools. Effectively, in our courses MATLAB has become a primer for C due to similarities in syntax. While teaching MATLAB as an introduction to programming is not new [5], direct interfacing between MATLAB and hardware still remains novel and non-trivial [6]. After going through systematic examination of our goals for the course, we came up with the revised course outcomes for ECE 102 as shown in Table 1.

Table 1. Course Outcomes – Students have the ability to …

ECE 102 Engineering Computation
1. Solve engineering problems by applying the engineering method
2. Analyze DC circuits using Ohm's law, Kirchhoff's laws, current-mesh methods
3. Process data using software
4. Develop algorithms in MATLAB to solve simple engineering problems
5. Use MATLAB programming for data acquisition and control
6. Communicate technical information in written and graphical format

To reinforce understanding of fundamental programming topics, a final practical project was added to both ECE 102 and 103. It requires the student to write programs that interface to and control sensors, LEDs, motors, and other electronic hardware. The projects are tailored to the students' skill level and are designed to be fun and interesting. While using microcontrollers or single board computers in a freshman engineering sequence is not a revolutionary concept anymore, the reasons for our choosing a particular type of interface device are somewhat unique. In many education scenarios in which an Arduino or Raspberry Pi controller is used, the interfacing task is the ultimate objective. In contrast, our primary goal is the teaching of the computing language, with hardware interfacing in a support role to increase student engagement.

After looking at various alternatives, we decided on an uncommon choice, the LabJack U3-LV from the LabJack Corporation. The LabJack is a measurement and automation unit that provides multiple analog/digital input and output lines, timers/counters, and SPI/I2C support. The LabJack connects to a host computer via a USB cable. For our purposes, the LabJack's multi-language support was a key feature that distinguished it from other, similar devices. It has a common API for both MATLAB and C/C++ (e.g., GCC and Microsoft Visual Studio). Students can program in these industrial-strength languages using each language's native development environment on the host computer, which is what they already use for homework assignments.

1.1. Course Organization

Because our university is based on a quarter system, it was a difficult task to fit all of the envisioned components into a ten week session. A further complication is that close to two-thirds of the students are transfer students, with most coming from local community colleges. Therefore, our student population has very diverse backgrounds, from experienced programmers to complete novices. Students also have varying degrees of prior college work, anywhere from true freshman to post-bac. For logistical reasons, we do not require ECE 102 as a prerequisite for ECE 103. It is, therefore, challenging to design a course sequence to accommodate all students so that some are not bored while others are overwhelmed with new material. As an illustration, our latest iteration of the ECE 102 schedule is given in Table 2.

Table 2. ECE 102 Course Schedule

Week	Topics	Week	Topics
1	Introduction / Units Problem solving	6	MATLAB branching LabJack overview / Interfacing 1 Final project introduced
2	MATLAB ops, variables, scripts Error analysis (significant figures)	7	MATLAB loops LabJack API / Interfacing 2
3	MATLAB vectors, matrices Tables / Graphs	8	Interfacing 3 MATLAB modular programming
4	MATLAB graphs Circuits 1	9	MATLAB strings / file I/O MATLAB data structures
5	MATLAB user-defined functions Circuits 2	10	MATLAB advanced topics Applications
		Finals	Project demonstration and report

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The LabJack is first presented about mid-way through the quarter, once branching and loop commands have been covered. Hands-on lab sessions are held to introduce the LabJack hardware and its programming functions. Students learn the procedures for sensing voltages, controlling LEDs, and reading switches. The lab exercises are synchronized with the lectures to provide a “real-world” application of each new programming topic. There is a multi-week final project in which two-person teams program a game that requires a hardware interface. Students are loaned a LabJack and an additional parts kit for constructing circuits.

In past years, the final project has been based on either the television game show “Wheel of Fortune” or the 80’s electronic toy “Simon”. For Wheel of Fortune, students build a circuit using a decoder chip and eight LEDs to simulate the wheel. Their MATLAB script monitors a switch that activates the wheel, controls which LED is lit as the wheel “spins”, and provides the game logic. In the Simon project, students implement the game with four LEDs and four switches. Their script generates the ever-increasing, randomized LED sequences, responds to switch presses, and performs the comparisons to see if the input matches the sequence. For extra credit, sound effects, music, or more elaborate displays can be added. A full design report with commented source code is required, and each team is expected to demonstrate and discuss their work with the instructor.

2. Course changes

In preparing for 2014-15 school year we decided to take advantage of some new opportunities to redesign the course. First of all, two instructors were assigned to teach separate sections of the course. This opened up opportunities for collaboration and testing of various hypotheses. Secondly, class size was set to a maximum of 50, which meant that experimentation with new pedagogy and tools would be easier and lower-risk than in 90+ sized classes of the past. After some initial discussions and given the newly agreed upon course outcomes, we decided to implement several changes:

1. Bring more in-class interaction by using an in-class response system
2. Partially “flip” the classroom by requiring students to read a MATLAB e-book and doing exercises before coming to class
3. Assign another mini group project to give students experience with group work and writing before they start working on the final LabJack-based projects

For the in-class interaction system, we settled on Learning Catalytics (LC) from Pearson [7]. It is a fairly flexible system that is more applicable in physical sciences and engineering due to its ability to handle LaTeX formatting and specialized questions, such as graphical input from students. Example of a working screen with all of the “lectures” that we set up for the course is shown in Figure 1. The system makes it easy to observe student performance in class so that the pace and questions can be adjusted to student progress. Within the system it is also possible to track individual students so that their participation and progress can be evaluated, as shown in Figure 2. This evaluation was done at the end of the class mainly due to lack of time, but to take full advantage of it, the evaluation would best be done periodically during the course.

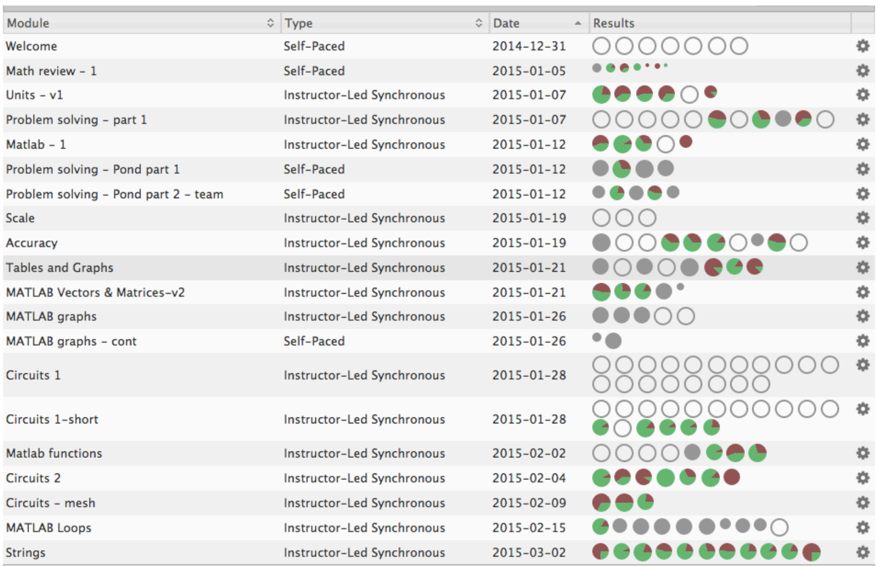
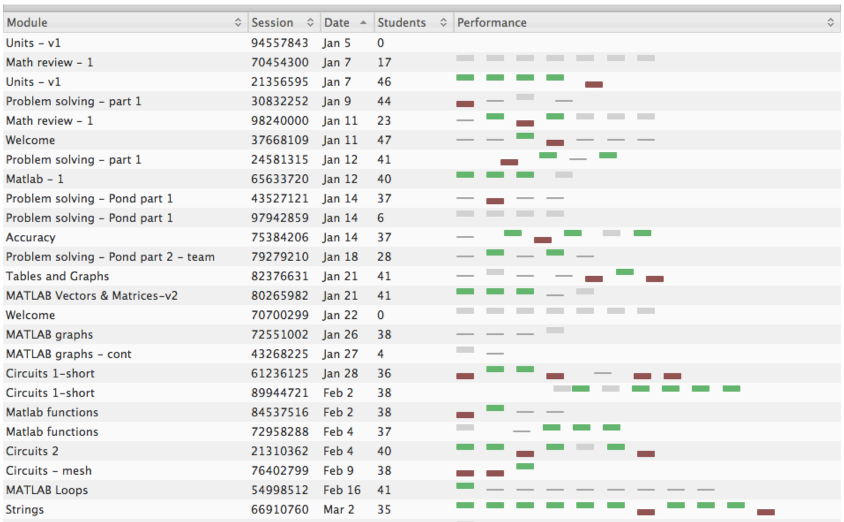


Figure 1. Illustration of sessions used in Learning Catalytics for in-class exercises.
Pie-charts indicate completion and correctness of answers.



Module	Session	Date	Students	Performance
Units – v1	94557843	Jan 5	0	
Math review – 1	70454300	Jan 7	17	
Units – v1	21356595	Jan 7	46	
Problem solving – part 1	30832252	Jan 9	44	
Math review – 1	98240000	Jan 11	23	
Welcome	37668109	Jan 11	47	
Problem solving – part 1	24581315	Jan 12	41	
Matlab – 1	65633720	Jan 12	40	
Problem solving – Pond part 1	43527121	Jan 14	37	
Problem solving – Pond part 1	97942859	Jan 14	6	
Accuracy	75384206	Jan 14	37	
Problem solving – Pond part 2 – team	79279210	Jan 18	28	
Tables and Graphs	82376631	Jan 21	41	
MATLAB Vectors & Matrices–v2	80265982	Jan 21	41	
Welcome	70700299	Jan 22	0	
MATLAB graphs	72551002	Jan 26	38	
MATLAB graphs – cont	43268225	Jan 27	4	
Circuits 1–short	61236125	Jan 28	36	
Circuits 1–short	89944721	Feb 2	38	
Matlab functions	84537516	Feb 2	38	
Matlab functions	72958288	Feb 4	37	
Circuits 2	21310362	Feb 4	40	
Circuits – mesh	76402799	Feb 9	38	
MATLAB Loops	54998512	Feb 16	41	
Strings	66910760	Mar 2	35	

Figure 2. Illustration of one student's performance and participation using Learning Catalytics.

So far, student participation in LC exercises is good at 70% to 80% of the whole population. Percentages are higher if we count only students attending the class. It usually takes at least one to two weeks for students who have never used the system to become comfortable and proficient in using it.

For assigned MATLAB readings, we settled on the e-book “Programming in MATLAB” by zyBooks [8]. This e-book system has been in use for several years and their MATLAB book was claimed to have improved student learning in a typical class environment [9]. The most attractive feature of the book is that it comes with interactive features and quiz-like questions that students can answer to test their understanding of the material they have just read. The system keeps track of how many exercises a student performs and generates reports that we can utilize to track student usage, as explained in the next section.

Finally, introducing a mini-project was reasonably successful. Most student groups were able to produce good quality reports, but we will not discuss this change in detail.

3. Course Assessment and Discussion

Student performance in ECE 102 is assessed in multiple ways: in-class exams (quizzes), homework sets, projects, and surveys. Final project success among the student teams is typically high, with completion rates in the 95% range, as shown in Table 3. We consider a project successfully completed if students can demonstrate its use as a “real” game machine, and if hardware and software satisfied all the requirements listed in our project guide. For example, all lighting and audio signals behave as specified. Students are given extra credit if they improve the game in some fashion but only if the core program performs as expected.

Table 3. ECE 102 Final Project Success Rates

Quarter	Year	# of Teams	% Successful
Winter	2011	31	94
Summer	2011	9	100
Winter	2012	35	94
Winter	2013	37	97
Winter	2014	36	89
Winter	2015	40	95

In-class exams have proven to be more challenging for students with a much wider variation in scores and are usually the most important contributor to variations in student final grades. We have been trying to identify variables that would explain success and failure in ECE 102 and other freshman classes, and math preparation is the usual suspect. However, as our previous work [10] has shown, the correlation between previous success in math and grades in ECE 102 is weak. We are currently examining some alternative hypotheses that we hope will be more predictive of student success.

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3.1. e-Book Readings

We monitored student reading of the e-book through weekly reports generated by the system. Figure 3 shows weekly completion rates for activities associated with MATLAB readings assigned for that week. Note that we eliminated from the pool the students who dropped the class. There were 43 students in Section 1 and 31 in Section 2. There is a significant difference in time evolution of completion rates among the two sections: starting from roughly the same point one stabilized at around 75% and the other at 40%. The main difference turns out to be that the instructor in Section 1 constantly reminded students of their assignments and posted weekly reading completion reports while the other one did not. Reading completion, however, was part of the overall grade in both sections. These two numbers seem to provide upper and lower bounds on what can be expected in terms of reading and activity completions. One may be tempted to explain these results by the fact that these are freshmen but our student population includes many "seasoned" students and only 38% are true freshman. Therefore, if it is deemed important to have students finish their readings it will require constant reminders of some type, independent of their status.

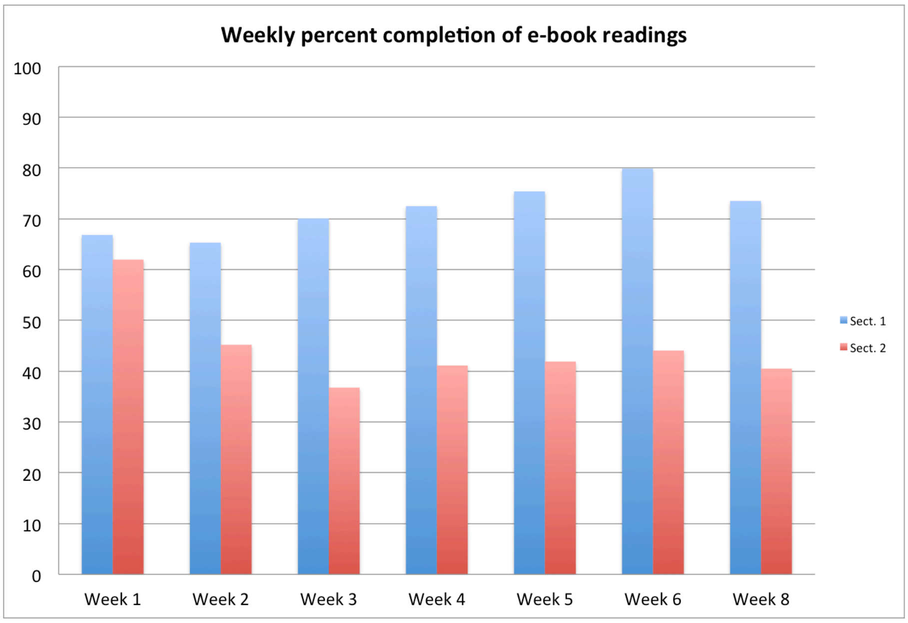

Figure 3. Weekly evolution of completion of activities from MATLAB e-book.

3.2. Survey

In order to assess effectiveness of various additions and changes to the course, we designed a new survey to probe student opinions about various components of the course. The full list of questions is given below and it is broken into two components: a) assessing student self-efficacy, i.e. their perception of their own ability to perform certain tasks, and b) perceived effectiveness of instructional techniques used in the class. Survey questions include:

A) *Self-efficacy ("I am confident that …")*
   Scale: Strongly disagree (1), Disagree (2), Neutral (3), Agree (4), Strongly Agree (5)
   1. I can program and use MATLAB to solve problems
   2. I can use MATLAB to control LabJack
   3. I can solve DC electric circuits problems
   4. I can solve general engineering problems
   5. I can write good quality reports

B) *Effectiveness of instructional techniques*
   Scale: Complete waste of time (1), Not helpful (2), Neutral (3), Somewhat helpful (4), Very helpful (5)
   6. Labs for building and testing circuits using LabJack
   7. Doing in-class exercises and problems (incl. Learning Catalytics)
   8. Solving homework problems
   9. Listening to instructor lecture
   10. Class projects

Figures 4 and 5 show the results collected from two sections, the first one with 31 out of 43 and the other with 32 out of 36 respondents.

Data from our survey regarding student self-efficacy is presented in Figure 4 where average scores for each question are presented. In general, there are no dramatic differences between the two sections with the possible exception of student confidence in solving DC electric circuits. More interesting is the fact that students seem to be fairly confident in their ability to solve problems. This is not entirely borne out by other assessment results. As mentioned above, project completion rates are very high. However, the quality of the final programs varies considerably, though it is difficult to judge consistently. We believe that this variation in quality reflects variation in student understanding of programming and problem solving and would indicate that students may be overly optimistic about their abilities. Quiz results provide another possible point of comparison. We have collected quiz results by question but have not yet completed a numerical analysis that would provide a comparison with student self-assessment. Our first impression is that students are overestimating their abilities, but we cannot quantify this observation at this time.

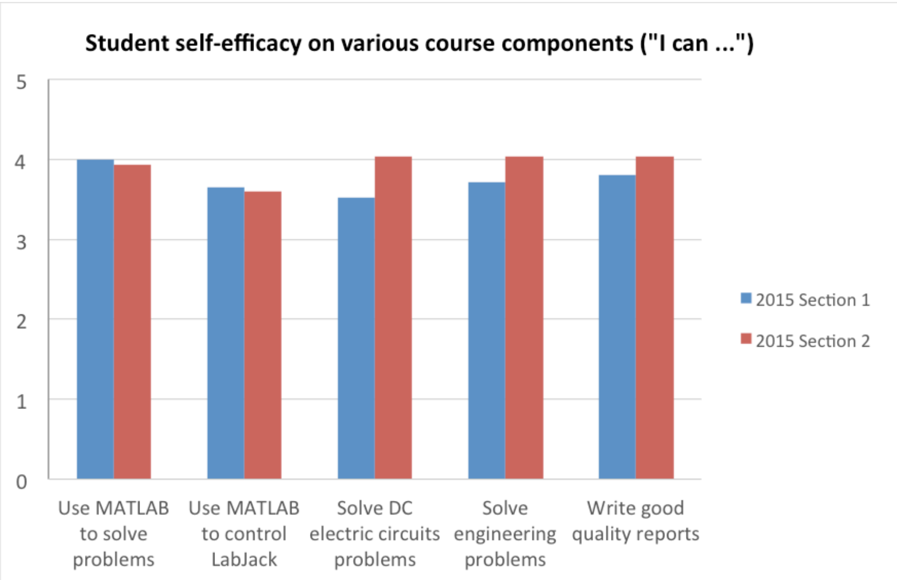

Figure 4. Student self-efficacy as determined by the end-of-term survey in Winter 2015.

Another set of questions on our survey deals with effectiveness of various pedagogical tools and the results are presented in Figure 5. In this case there are some differences between two sections. In particular, lectures in Section 1 were deemed significantly less effective than in Section 2. This may be attributable to the fact that the instructor in Section 1 taught the course for the first time, while the second instructor has many years of experience in teaching this or similar courses. Given that the students are “neutral” (i.e. numerical score around 3) with respect to helpfulness of LabJack in understanding MATLAB, we should strengthen the connection between MATLAB and LabJack possibly by adding another lab or more discussions in class. Interestingly, students still value homework exercises more than doing similar problems in class. This is puzzling because one of the persistent student complaints is regarding lack of feedback on homework problems, but when we provide immediate feedback during class that does not seem to be perceived as an improvement over homework. Alternatively, it is possible that our implementation of in-class exercises is not yet fluent and polished, and we will have to examine trends over time. It is also quite possible, as evident in some student comments, that students are not used to this mode of instruction. Finally, it is interesting to note that students like the MATLAB e-book better than the paper textbook used in 2011. Again, we will monitor how this item develops over time.

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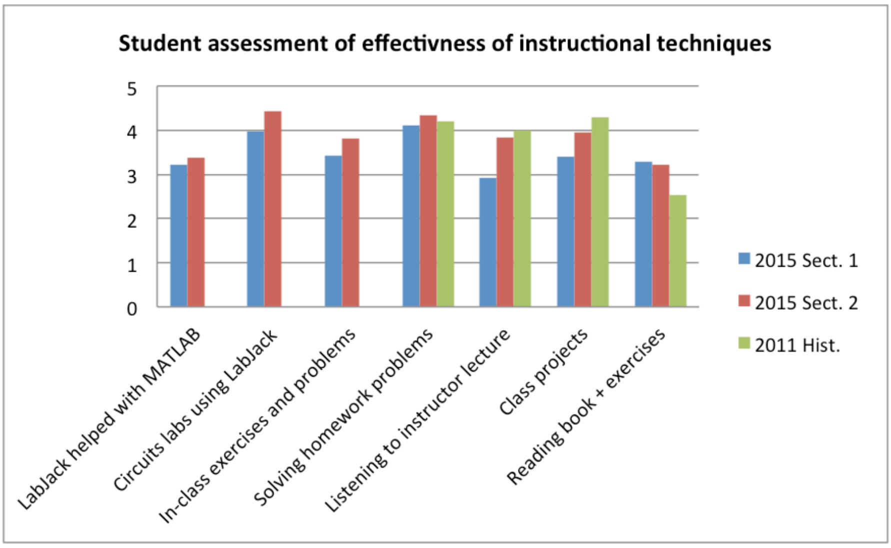

Figure 5. Effectiveness of instructional techniques as determined by the end-of-term survey in Winter 2015.

Finally, we also looked at some student comments on the survey. From a previous survey in 2011 we know, for example, that many students stated that they enjoyed the practical aspects of the project, which maintained their interest. On the other hand, a common complaint at that time was the significant amount of time it takes to develop and debug code.

From the 2015 survey it appears that not all students bought into the active learning and flipped approach, so one of them complained “The teacher needs to teach, not just show and have us read an online book” but others felt that “In-class and group activities are extremely helpful.” For using the e-book, there are similarly mixed opinions, from: “The zyBook was not very helpful for me. The book was a good idea but I think something else could help more”, to: “The zyBook was alright, but grading the reading on that is a little lame as it doesn't really indicate if the material was learned.” Many students complained about lack of practicing MATLAB and we have starting implementing a set of labs that will help train students better. In parallel with that development we will experiment with competency testing.

4. Conclusions

The ECE 102 Engineering Computation course has evolved over time in both content and teaching philosophy. It was always meant to provide students with practical problem solving skills while at the same time teaching them the basics of programming and electrical engineering. In 2015 we incorporated more active learning tools, such as interactive online textbooks and real-time assessment of student responses to questions using the web-based Learning Catalytics. We have presented our implementation and discussed some problems that have arisen. From our initial assessment it seems that some students have not yet fully accepted this instructional approach. Furthermore, just assuming that students will take over the responsibility for their learning is likely to result in disappointment. In our case this was reflected in the fact that without constant reminders in the form of weekly grades, students were much less likely to complete their reading assignments. Overall, this was a successful first test of the effectiveness of more active in-class engagement and the utilization of an e-Book as primary reading material for MATLAB programming. Despite the initial difficulties, we feel that the time and effort invested in this change was well worth it. Our first corrective action will be introduction of programming labs and competency testing, both of which are aimed at strengthening student programming skills.

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Innovative Engineering Education through Modular Teaching with Emphasis on Design

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Abstract

This paper presents an innovative approach for teaching upper-level engineering classes. It includes a faculty team where each faculty covers their area of expertise related to a semester long design project. While traditional lecturing has been shown to be passive and requires minimum student interaction. This approach facilitates learning by reducing inactive learning and replacing it with well-developed inter-related modules and hands on goal oriented design experience. This set-up reinforces learning and encourages the learner to think and get involved in his/her education. Each module is a self-contained unit dealing with specific concepts in the course. Modules are assessed with pre-test, post-test, and its contribution to the overall design project success. The integration of term-long design will emphasize inter/intra module concept understanding and improve student involvement. Additionally, this article discusses results obtained from two National Science Foundation (NSF) funded projects using this approach: one in robotics and another in Nano-electronics. The modular design method used in these two classes has proven to be an effective teaching method.

Keywords: *Teaching by design, Modular teaching.*

1. Introduction

It is well known to engineering faculty that hands-on interactive laboratory based learning has a direct impact on student's learning outcomes and induces a higher level of confidence and motivation [1] [2]. However, it has also been shown that hand-on experiments alone do not lead to deep conceptual understanding and problem solving skills [3]. Traditional caned laboratory experiments (when students follow the procedure step-by-step) fail to engage students to think like a problem solver. Students merely follow instructions with limited mental engagement and conceptual understanding of the material. In this paper, use of ill-defined and/or open-ended design problems in an interactive hands-on setting with a modular teaching method is presented as a solution to this problem. Modular teaching allows interaction with a faculty expert in that module. The role of the faculty expert is enormously important, without his interventions the students' frustration will keep them from reaching the deep understanding required for engineering subject comprehension.

2. Modular Teaching

In today's multidisciplinary world, teaching a complex engineering course from the point of view of a single expert in one of the disciplines is neither efficient nor sufficient. Modular teaching allows a course to be divided into multiple modules. Each module is then taught by a faculty specialized in that area. Modular teaching not only can improve learner's outcomes but also can make the courses more manageable, divide and conquer.

2.1. Online Versus Traditional

Each module may be taught in a traditional classroom setting or online. The team members may also be from various institutions creating a virtual team. The online capability opens the door to smaller schools with limited expertise. Additionally, they can now offer specialized courses that would never made before due to the fewer numbers of students interested in the topic, through sharing expertize and offering multi-institutional online modules. As an example: in one of our projects we lacked local expertise in nanoscale fabrication and we were able to offer the module with the help of a colleague in another institution. Modern technological tools offer the opportunity for interdisciplinary virtual student teams learning through collaboration on a term-long complex problem with multiple experts from all over the world. However, it must be noted, there are some negative effects associated with pure online learning such as: reduced ability to learn from peers, lack of human interaction, and frustration with interface technology which in turn can be demotivating and have a negative

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effect on the learning outcomes. Some of these obstacles can be surmounted simply by intrinsic motivation of students [4].

2.2. Collaborative Teaching and Learning

We rarely accumulate knowledge in isolation, rather, in learning communities. Each module and its expert is in fact a small, task specific learning community. In these communities learning happens when students are focused on solving their term-long problem. They are learning from experts and they are learning from each other. As they learn from each other they start acting as experts which results in improving their and their classmates' confidence. This teaching-learning synergy makes them realize that they can figure things out for themselves and that is when true learning begins.

3. Design Component

A term long design oriented project will provide ample opportunities to collaborate on complex engineering problems and realize solutions with guidance from experts. The ultimate goal of this method is to not only teach theory through application, but also to teach critical thinking and problem solving skills that will open up new avenues of learning for the students. Next, we look at the similarities and differences between traditional laboratories and remote laboratories.

3.1. Traditional Laboratories versus Remote Laboratories

A comprehensive study of remote laboratories [5] has illustrated their fundamental differences with traditional laboratories. Remote labs provide a different learning experience and are not a direct substitute for traditional labs. While traditional laboratories work well for local teams with available on-campus facilities, remote laboratories become essential for virtual teams or when local laboratory facilities are not sufficient. When appropriately used (in combination with other parts of the course) they can offer many advantages such as flexibility in system access time and its user environment. Both of which can result in higher learning outcomes due to greater student control and better linking of design and theory.

4. Student Performance Evaluation

The students' performance is continuously evaluated thought the term. There are module evaluations at the beginning and end of each module. There is a final concept inventory (or similar evaluation) at the end of each term. Most importantly, term projects are evaluated based on their bi-weekly progress reports, final report, and final presentation and demonstration.

4.1. Class Size Matters

Breaking up a large course to be taught in parallel modules will result in smaller classes. This side effect by itself creates a better learning environment. In a controlled study performed during spring of 2015, two sessions of the same course were taught by the same instructor who has taught the class for the last 12 years. One session had 56 students while the other had 82 students. The lectures were identical; so were the assignments and examinations. As a matter of fact, the assignments and examinations were done together as this was a very large class.

The following table (Table 1) shows the students' end of semester instructor/course evaluation for both sessions and the student outcome according to their average course grades. It becomes obvious from both high data correlation between classes and results of unpaired *t*-test that class size matters beyond statistical significance. A meager 32% reduction in class size can result in substantial course outcome and student performance improvement.

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Table 1. Course evaluation and student performance data for two identical classes with different sizes. Evaluations are on a 5-point rating scale where a 5 indicates excellent (the course performance values are normalized to be on a scale of 0-100).

	Course Session 001			Course Session 002			Other Classes		
Description	Total Resp.	Avg	Std Dev.	Total Resp.	Avg	Std Dev.	Dept Mean	College Mean	Univ Mean
Considerate of the students during class	82	**4.46**	0.57	56	**4.61**	0.59	4.53	4.49	4.51
Presents the subject matter in a clear and organized manner	82	**4.38**	0.60	56	**4.59**	0.65	4.44	4.37	4.41
Tests and other requirements cover the course description in the syllabus	82	**4.38**	0.60	56	**4.57**	0.65	4.51	4.48	4.52
Sets high academic standards	82	**4.37**	0.69	56	**4.57**	0.62	4.44	4.45	4.49
Lectures focus on the material outlined in the syllabus	82	**4.30**	0.82	56	**4.54**	0.65	4.46	4.45	4.50
Attempts to involve students in class discussions/activities	82	**4.17**	0.78	56	**4.46**	0.71	4.37	4.38	4.47
Textbook support the course objectives	82	**4.30**	0.68	56	**4.48**	0.65	4.42	4.43	4.48
Communicates the importance of the subject matter	82	**4.35**	0.65	56	**4.57**	0.62	4.43	4.43	4.48
Uses examples to help students understand	82	**4.37**	0.65	56	**4.59**	0.62	4.41	4.41	4.47
Course grade (assignments, exams, and final)	82	**73.3**	7.2	56	**78.2**	7.7	By conventional criteria, unpaired *t*-test shows this difference to be extremely statistically significant		

5. The Case Studies

In this section, we describe applications of this method and present its outcomes through formalized and systematic funded research projects. We present three case studies of modular teaching with a hands-on design approach in various STEM areas: a short course in programming to middle school students [6], a two-semester long robotics education program [7], and a research oriented Nano-electronics course for engineering students [8].

5.1. Academy Lego Programming Project

This was our first project well over ten years ago and funded by an academy fellowship grant from Texas A&M University System Regents' Initiative for Teaching Excellence. We showed middle school children how to build and program Lego robots for weekly competitions to solve a series of ill-defined, open-ended problems in an interactive hands-on setting. Two instructors covered mechanical design and programing modules for the course. The mechanical design of the manipulator and its programming were introduced as the students struggled with their solutions and started searching for more information and trying new approaches [6]. It is interesting to note that today more than 20% of those middle school students are majoring in engineering which is considerably above the national average.

5.2. NSF Nano-electronics Project

In this project, a state-of-the-art Nano-electronics course is taught to undergraduate students in a minority serving institution with limited research capabilities. The course is partitioned into four essential modules and guided by four faculty members with expertise in their module. The course modules are nanoscale fabrication and characterization, modeling and computational nanotechnology, nanoscale devices, and nanoscales circuits. All modules are taught locally except the fabrication module which was taught by an expert in nanofabrication at the Georgia Institute of Technology .The main object of the course is to teach Nano-electronics concepts from materials to systems and to educate research oriented students with well-balanced foundation in nanotechnology research and development [8] [9].

The course's interactive design component is a semester long research project. The research project provides hands-on experience with experiment design, sample fabrication, physical and electrical characterization of samples, as well as modeling and simulations with high performance computing clusters.

A formal course evaluation is conducted at the end of each module and at the end of semester. Tabulated evaluation results indicate that students felt well prepared in the area, took pride in their project, and increased their knowledge and interest in nanotechnology research.

A concept inventory is developed [10] by the faculty team and administrated to the students at the end of each semester. The outcomes validate the students' competence in the Nano-electronics area and show a high correlation with their research projects. Furthermore, the students' learning outcomes can be validated by their performance after the course. Two teams continued their research work beyond the first semester and one team secured the College of Engineering Prestigious Senior Design Award for their work in Nano-electronics.

5.3. NSF Robotics Project

In this project, a two-semester multidisciplinary project based robotics program was developed [7] [11] for undergraduate electrical engineering, mechanical engineering, and computer science students. The program is taught over two semesters. Additionally, each semester is broken to five modules. Each module is assigned to a faculty with expertise in that area. A multidisciplinary team of faculty members from electrical engineering, mechanical engineering, and computer science are selected for the course modules. The modules for the first semester are locomotion, robot kinematics, mobile robot kinematics, actuators, and sensors-I. The second semester modules are Sensors-II, communications, localization, planning and navigation, and practical mobile robots.

During these two semesters, multidisciplinary student teams design and implement a mobile robot for IEEE region-5 competitions. The top team from each class gets to compete as school representative in IEEE competitions that year. The competition's rules and design requirements can vary tremendously from year to year which makes the competition even more challenging [11] [12].

A series of evaluation surveys designed and conducted by a professional external evaluator has shown the effectiveness of this program in teaching an interdisciplinary robotics class. In general, students consistently rate their interactions with module faculty, laboratory work, and competitiveness nature of the course very high. They also give high marks for improved skills like teamwork, design, and innovation in addition to technical knowledge gained such as understanding sensors, actuators, kinematics, communications, and locomotion.

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6. Conclusion

In this paper a novel approach for teaching complex STEM courses has been presented. It has been shown that modular teaching in conjunction with a long-term design project which covers multiple facets of the course materials from various experts' points of view can create pronounced teaching-learning synergy. The modular structure provides enough flexibility to teach the course in smaller institutions and/or smaller classrooms with limited local expertise. Remote modules can be combined in many smaller units to be guided online by a single faculty expert in that module. From case study survey results we can confidently state that hands-on activities when associated with a long term goal not only improve class participation but also increase learning outcomes.

7. Acknowledgements

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Enhancing Student Performance through a Competitive Team Tournament

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Abstract

In some engineering subjects, the nature of the material requires a maturation time in the student's mind before being fully understood and the time constraints of modularization can become an impediment to the successful achievement of their learning outcomes. This paper presents a novel and efficient way of helping students to timely meet their learning outcomes by means of a Team Game Tournament. The principle behind a Team Game Tournament is that the success of a team lies on the success of the individuals composing the team. Therefore, team mates help each other and study more than individually because they care for them and for the team. A variation of Team Game Tournament inspired by the UEFA 'Champions League' is used here to address learning outcomes for two different age groups, four modules, four engineering degrees and two countries during the 2013/14 and 2014/15 academic seasons. It is noticed that the more games between the teams, the more effective the team work and learning has become. Confidential questionnaires and end-of-semester exams confirm the success of the competition in enhancing student satisfaction and learning.

Keywords: *Team Game Tournament, Cooperative Learning, Student Engagement.*

1. Introduction

Engaged students are successful students and the ongoing challenge for educators is how best to engage students during instruction [1]. There is evidence in the literature that games can be fun, highly motivational and help people to learn something challenging while enjoying it. Two games based on television shows ('*Family Feud*' and '*Name that Tune*') are used to teach content and enhance students' critical thinking abilities in nursing [2]. A game-based approach, this time, based on a sport competition ('*The Champions League*'), is used to promote active learning in civil engineering [3]. In both cases, the class is divided into teams that play against each other, i.e., solving problems posed by the facilitator or themselves. Often, clicker-based software (also known as Student Response Systems), also has options to introduce team competitions or games to make the questioning more attractive to students.

More specifically, the approach by [3] is based on a Team Game Tournament (TGT). TGT, first introduced by [4], falls within a type of cooperative learning methods known as *Structured Team Learning* (which also includes Students Teams-Achievement Divisions, Team Assisted Individualisation and Cooperative Integrated Reading Composition) [5]. All cooperative learning types have the following pillar stones in common [6]-[8]:

- *Positive Interdependence*: Students must perceive that each group member is linked to others in a way so that a group member cannot succeed unless others do.
- *Individual Accountability/Personal Responsibility*: Each member must contribute to the group and be accountable for helping the group reach its goals. The performance of each student is assessed and the results are given back to the group and the individual.
- *Face to Face Interaction*: Each group member promotes each other's success by helping, encouraging, and supporting each other's efforts to learn.
- *Interpersonal Skills*: Each group member must be motivated, provide effective leadership, be able to make decisions, to build trust, to communicate and to manage conflict, etc.
- *Group Function*: It is necessary to ensure group members openly discuss how well they are achieving their goals and maintain effective working relationships.

The aim of this paper is to test a form of TGT that combines the benefits of cooperative learning together with the high levels of engagement achieved by students in games and sports. It is expected to enhance student learning and satisfaction significantly via this novel form of competitive teamwork, which involves rewards to teams based on the learning progress of their members. The main objectives of the intervention are:

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- developing an efficient way for students to practise the material taught in lectures and to meet the learning outcomes,
- promoting critical thinking, and provide feedback to students if further study was needed,
- promoting peer-learning by helping other team mates,
- promoting high levels of retention,
- making tutorials more fun and engaging,
- making students work harder, and
- making students better team players.

2. The Intervention

This paper builds on the work by [3] to extend a variation of TGT inspired by the UEFA '*Champions League*' to multiple backgrounds in the 2013/14 and 2014/15 academic seasons including students:

- at two stages of their degree: 3rd and 4th year,
- in four modules: Surveying; Elasticity; Analysis of Structures; Structural Analysis, Design and Specification,
- in four engineering programmes: Forestry and Natural Resources Engineering; Civil Engineering; Structural Engineering with Architecture; Engineering with Science and
- in two Universities/Countries: University College Dublin (UCD, Ireland) and University of Oviedo (UO, Spain).

2.1. The Sample

The number of students registered at each of the programmes and modules under investigation is listed in Table 1. In the second row of this table, "Trad." stands for the academic season where tutorials have been carried out in a traditional format (2012/13 for the three modules in UCD and 2013/14 for the module in UO) and "TGT" stands for the seasons where the new intervention hast taken place (2013/14 for the three modules in UCD and 2014/15 for the module in UO). Here, a traditional format to deliver tutorials refers to a facilitator providing a question or number of questions that students must answer and submit within an allocated time.

Table 1. Number of students registered to each module and programme.

Module	Programme	No. students Trad.	No. students TGT
Elasticity (UCD)	3rd year Civil Engineering	21	16
	3rd year Structural Engineering with Architecture	13	15
	Total	34	31
Analysis of structures (UCD)	3rd year Civil Engineering	20	19
	3rd year Structural Engineering with Architecture	15	13
	Total	35	32
Structural analysis, design & spec. (UCD)	4th year Civil Engineering	41	11
	4th year Structural Engineering with Architecture	25	13
	4th year Engineering with Science	6	4
	Total	72	28
Surveying (UO)	3rd year Forestry and Natural Resources Eng.	22	27
Total (UCD + UO)		163	118

Table 2 provides details on the sample regarding the gender ratio and the number of national and non-national students. It must be noted that students experience this variation of TGT by the first time in all modules, except in '*Analysis of Structures*' (2nd semester of academic season 2013/14) when most of them already saw TGT in '*Elasticity*' (1st semester of academic season 2013/14).

The questions in a TGT round relate to relevant learning outcomes taught at the time in lectures. In '*Elasticity*', learning outcomes involving calculation of stresses and strains, constitutive equations, Mohr's circle and stress functions are tested with TGT. In '*Analysis of Structures*', calculation of internal forces and displacements in statically indeterminate structures and influence lines are topics subject to TGT. In '*Structural Analysis, Design and Specification*', moment distribution, elasto-plastic analysis of beams, yield analysis of slabs, reinforced concrete columns and prestressed beams are covered. Finally, in "*Surveying*", prevision vs accuracy, random error theory, random error propagation and basic concepts on Geodesy and Cartography are the themes for the TGT matches.

Table 2. Characteristics of the sample.

Module	Total no. of students		Male/ Female		National/ Non-National	
	Trad.	TGT	Trad.	TGT	Trad.	TGT
Elasticity (UCD)	34	31	29/5	24/7	30/4	26/5
Analysis of structures (UCD)	35	32	31/4	23/9	29/6	28/4
Structural analysis, design & specification (UCD)	72	28	58/14	23/5	59/13	24/4
Surveying (UO)	22	27	15/7	20/7	21/1	27/0
Total (UCD + UO)	163	118	133/30	90/28	139/24	105/13

It must be noted that the overall score in the modules under investigation is calculated from a weighted sum of continuous assessment results and an end-of-semester examination. Continuous assessment consist of tutorials (and labs in some cases), and it is within these tutorial slots that TGT is implemented. The percentage distribution of marks between Exam/Tutorials/Labs towards the overall grade is 80/10/10 for '*Elasticity*', 80/15/5 for '*Analysis of Structures*', 80/20/0 for '*Structural Analysis, Design and Specification*' and 60/20/20 for '*Surveying*'.

2.2. The Tournament

The competition is established by dividing the class into a number of small academically balanced teams that play against each other. The classes under investigation have a size of about 30 students (Table 2) that are divided into 4 teams. The composition of each team is maintained throughout the tournament. Two simultaneous matches take place in 2 h slots allocated to tutorials. The teams are paired against different opponents for each tutorial. During a match, students sit together at the table of their team (Figure 1).

(a) UCD (Ireland) (b) UO (Spain)

Figure 1. Arrangement of teams for the competition

A specific match between two teams, 'A' and 'B', consists of posing questions (one question per team player) to the opponent team and answering the opponent's questions. In the four TGTs, the questions assess knowledge that requires calculations and numerical solutions. In the case of a game between two teams with 4 players each, there will be a total of 8 questions and 16 answers. During the 1st hour, the students prepare the questions and their solutions. For example, in Figure 1(a), each student 1, 2, 3 and 4 of team A produces one question (Q1(A), Q2(A), Q3(A) and Q4(A)) and the solution (S1(A), S2(A), S3(A) and S4(A)) to his/her own question Figure 2(a)). At the end of the 1st hour, the facilitator collects all questions and solutions by all teams. At that point, the solutions (S1(A), S2(A), S3(A), S4(A) by team A, and S5(B), S6(B), S7(B) and S8(B) by team B are stored by the facilitator, who right after interchanges the questions between the teams (Figure 2(b)).

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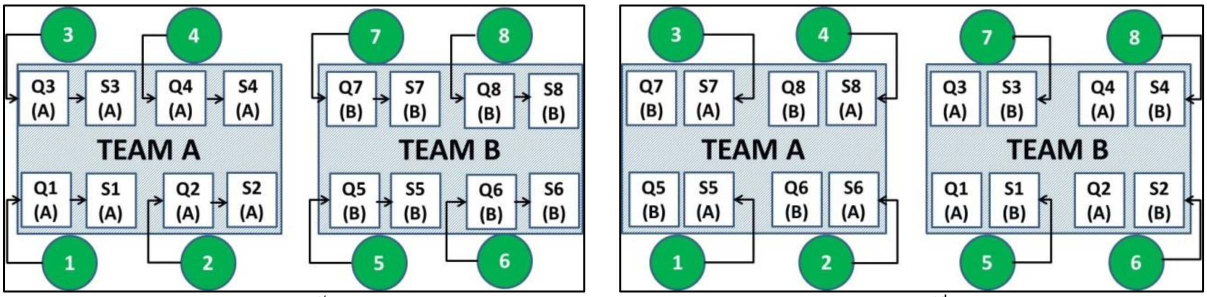
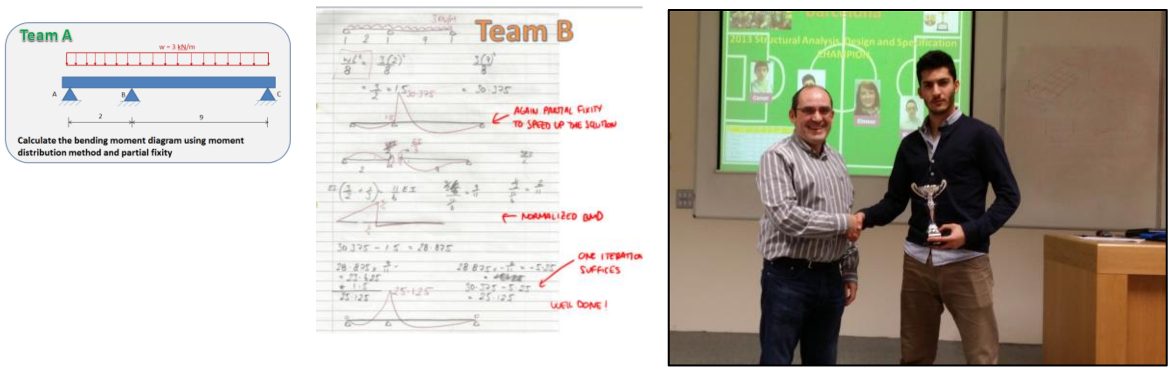


(a) 1st hour (b) 2nd hour

Figure 2. The two halves of a match

Students are held accountable for their own questions and answers, and also help and learn from their team mates as they want their team to win. Students are rewarded according to their individual performance (80 % of the total TGT score is assessed individually depending on how challenging the question of each student is and the accuracy of his/her answers) as well as their team performance (20 %, 10% and 0% are obtained for a victory, draw and defeat respectively towards the total TGT score). To decide the winner a match, solutions from students from both teams to the same question are compared together. If the solution by one student is better than the answer by a second student, then, the team of the first student will score a goal in their favour. However, if both solutions are equally good or poor, then, none of the two teams score. By adding the goals achieved counting all students in the two teams playing against each other, it is possible to obtain a final match result. Selected questions posed by the students and their solutions are scanned and discussed in lectures after completion of a round (Figure 3(a)). In UCD, these questions are made available online via a Blackboard VLE. There is a schedule with pre-stablished dates for the games and an overall classification that is updated after each round/tutorial. At the end of the competition, the champions are rewarded with a prize (Figure 3(b)).



(a) Feedback in lectures (b) Player of winning team collects trophy

Figure 3. Follow-up of tournament

3. Student Feedback

This Section reports on how students feel about the intervention. There are three types of feedback: An online end-of-semester survey, confidential questionnaires before completion of semester and open-ended comments.

3.1. Survey at the end of Semester

UCD collects information on answers to a survey with core questions on each module that are repeated every year through an online Blackboard VLE. The impact of the TGT intervention in 2013/14 is very obvious when compared to previous years when a traditional tutorial format has been employed (Figures 4(a) to (e)). The values in the figures below correspond to the average obtained from the score assigned by students according to a Likert scale with 5, 4, 3, 2 and 1 being “Strongly Agree”, “Agree”, “Neither agree nor disagree”, “Disagree” and “Strongly Disagree” respectively. Although results are very positive and peak values can clearly be seen in 2013/14, they must be interpreted with caution as only a small percentage of the class typically fills the online feedback (Figure 4(f)) and some do it after the end-of-semester examination which could introduce some bias in the answers.

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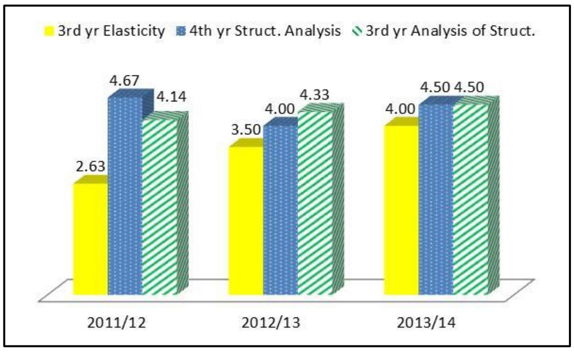
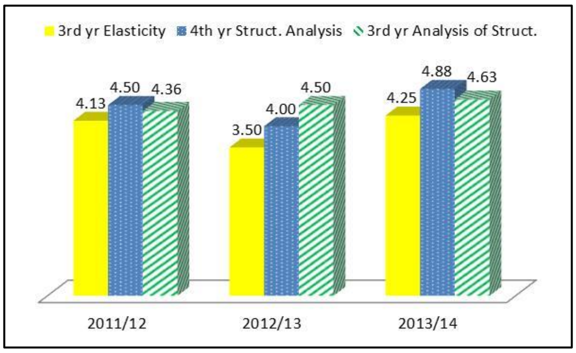
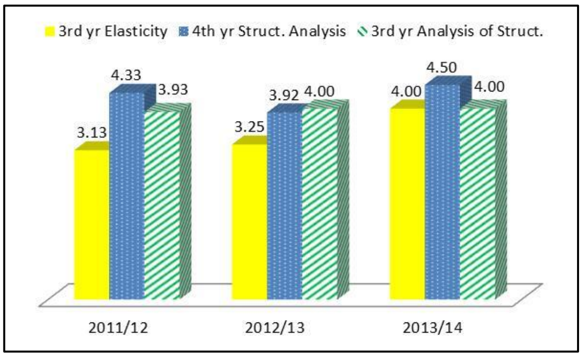


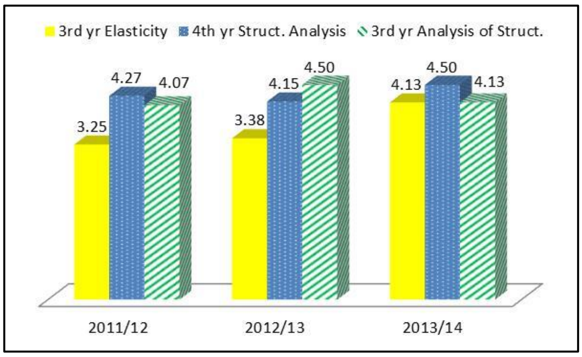
(a) I have a better understanding of the subject after completing this module



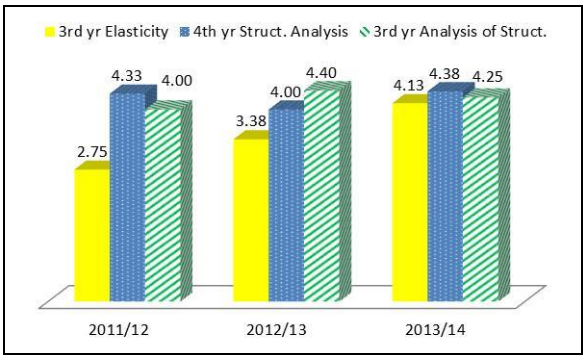
(b) The assessments to date were relevant to the work of the module



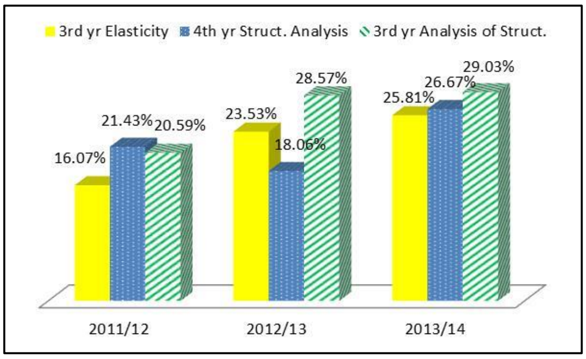
(c) I achieved the learning outcomes for this module



(d) The teaching on this module supported my learning



(e) Overall I am satisfied with this module



(f) (%) responses from total registered students provided in Table 1

Figure 4. End-of-semester survey

3.2. Confidential Questionnaires during the Semester

A hard copy confidential questionnaire focused on the fulfilment of the objectives of the intervention is circulated amongst students during lectures once the TGT has started and before the end-of-semester examination takes place. The questionnaire was not distributed to '*Analysis of Structures*' students as most of these students already took the same questionnaire in 'Elasticity'. The level of participation is 67.7 %, 82.1 % and 70.4 % for '*Elasticity*', '*Structural Analysis, Design and Specification*' and '*Surveying*' respectively with respect to the total number of registered students given in Table 1. Student absenteeism and dropout rates are extended problems in Universities [9] [10] that commonly prevent a higher % of responses. Figure 5 shows that positive results are found for all modules under investigation. Again a Likert scale is employed with 5, 4, 3, 2 and 1 corresponding to "Strongly Agree", "Agree", "Neither agree nor disagree", "Disagree" and "Strongly Disagree" respectively.

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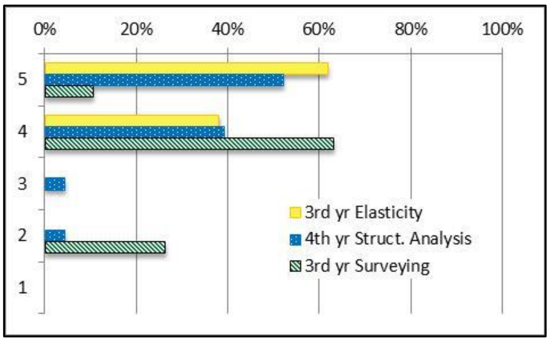
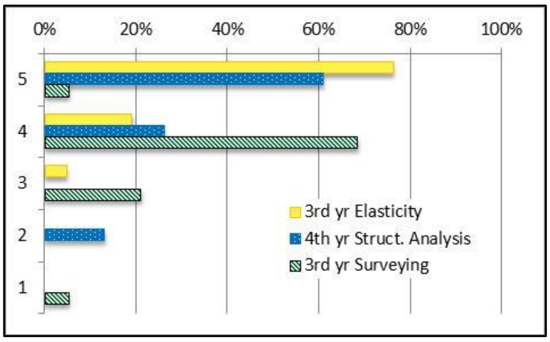
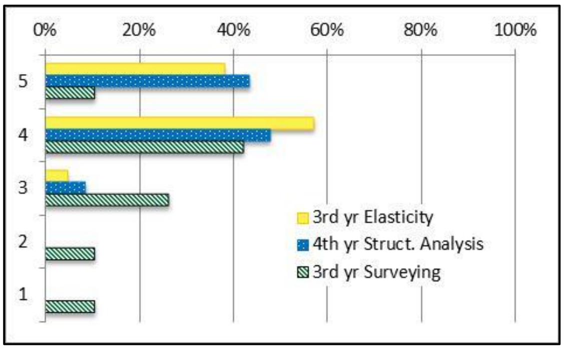


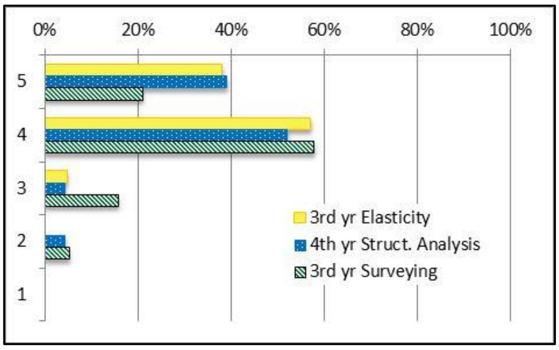
(a) The new tutorial format is efficient in allowing me to practice the material taught in lectures



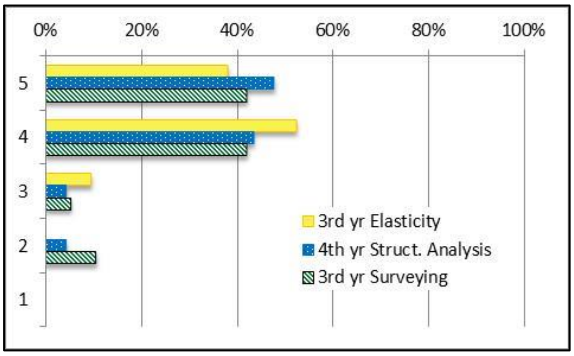
(b) Defining questions and answers and solving other team's questions let me reflect on the topic and makes me aware of what I must revise/reinforce



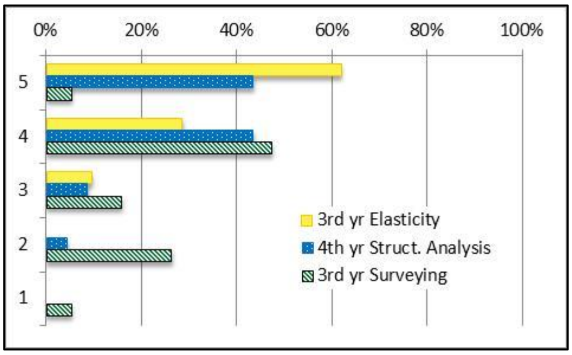
(c) I work harder to improve the score of my team



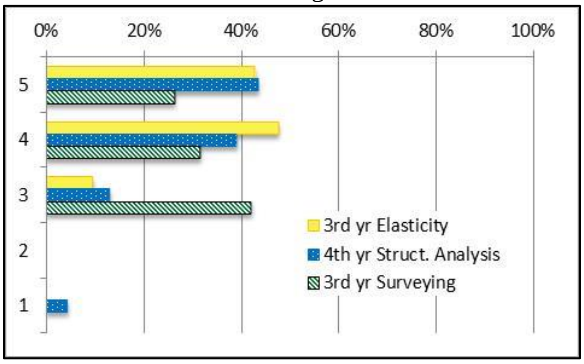
(d) I help my team mates during or for the games



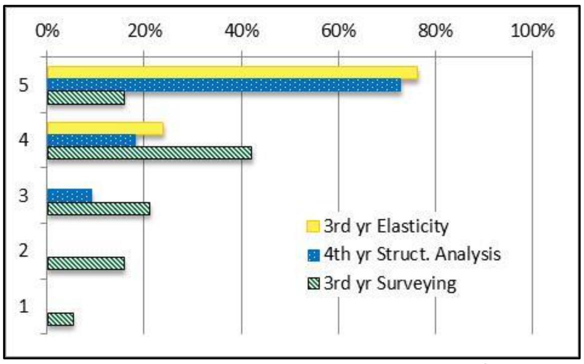
(e) I am provided assistance by my team mates during or for the games



(f) I enjoy participating in the tournament



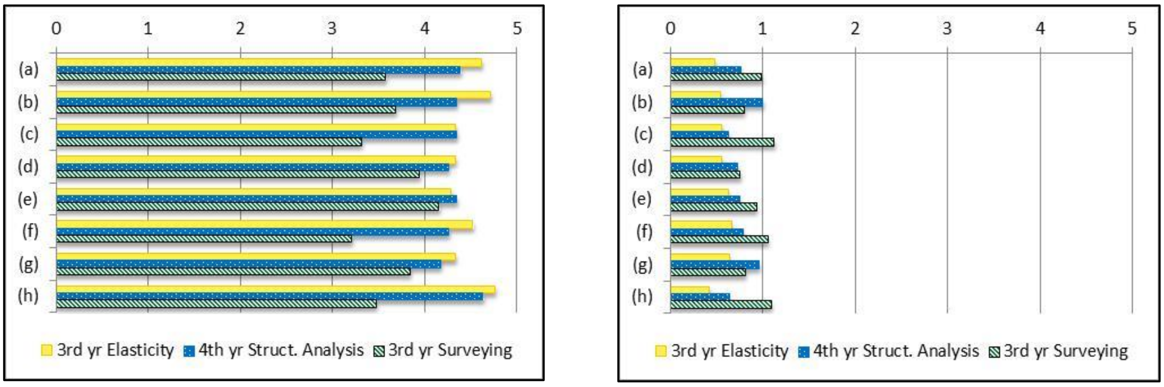
(g) My links with my peers are being strengthened during the tournament



(h) Overall I recommend using this tutorial format in the future

Figure 5. Results from confidential questionnaires

Figure 6 provides the overall statistics (mean and standard deviation) for answers in '*Elasticity*', '*Structural Analysis, Design and Specification*' and '*Surveying*' to questions (a), (b), (c), (d), (e) and (f) defined in Figure 5. It can be seen that mean results for '*Surveying*' are consistently lower than in the other two modules. These differences between the modules at UCD and the module at UO can be attributed to a lower level of dissemination of the *Champions* in UO and to a human factor. Here, dissemination refers not only to the communication of partial results and overall classification which are periodically updated online in UCD via Blackboard, but also to the large database of questions and answers generated by the students and made available to them via the same platform. Unlike '*Elasticity*' and '*Structural Analysis*, *Design and Specification*', the lecturer for '*Surveying*' is not the same person as the 'TGT' facilitator, and possibly, the connection between lectures (i.e., including feedback) and TGT has not been established to the same extent. Another possible cause is that a TGT based on '*The Champions League*' may not be as appealing to female students as to male students. Therefore, the proportion of female students in '*Surveying*' (Table 2) is significantly larger than in the other modules. The larger standard deviation in '*Surveying*' is evidence of a more spread variety of opinions about the intervention.



(a) Mean (b) Standard deviation

Figure 6. Overall statistics

3.3. Comments

Some open ended comments from the confidential questionnaires are reproduced literally below:

"*Champions League format of tutorials was fun, engaging and helped learning, lots of examples helped understanding*"

"*Good creative idea that makes tutorials fun*"

"*Champions League was very enjoyable and really helped our learning*"

"*Champions League made me work harder, and made me aware of what I was falling behind on*",

"*The new tutorial style of doing matches was brilliant and made a definite difference to my learning*"

"*I have a keen interest in the Champions League, so the theme was very entertaining. The idea of competing against someone while also being able to work as a team was thrilling. Strongly recommended!*"

"*Very enjoyable + I feel I am learning a lot more*"

"*I love the Champions League*"

4. Impact on End-of-Semester Exams

In the academic season prior to the application of the TGT intervention, the average score in the end-of-semester exam was 39.8%, 49.7%, 52.5% and 36% for 3rd year '*Elasticity*', 3rd year '*Analysis of Structures*', 4th year '*Structural Analysis*, *Design and Specification*' and 3rd year '*Surveying*' respectively. It must be noted that the pass threshold is set at 40% in UCD and at 50% in UO.

In the three UCD modules under investigation, the end-of-semester exams represent 80 % of the overall grade. The content representing TGT material represents approximately 50 % of the syllabus assessed in the exam. As a result of the intervention, the average exam score increases by 7.9 %, 5.1 % and 4.8 % in '*Elasticity*', '*Analysis of Structures*' and '*Structural Analysis*, *Design and Specification*' respectively, compared to the previous academic season. The impact of TGT is felt more significantly in the modules that are apparently more difficult to students, i.e., with a lower average exam score.

In the UO '*Surveying*' module, the end-of-semester exam weighs 60 % of the overall grade. However, this exam is theoretical and the practical material tested in TGT is assessed within the remaining 40% allocated to the continuous assessment. Under these circumstances, the effectiveness of TGT cannot be compared to UCD in the same terms. Even so, the positive effects of TGT may be indirectly captured (i.e., students liking and understanding the subject better) in an increase of the average score of the theoretical exam by 4.2 %, and in a

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very significant increase of the final module score (combining both exam and continuous assessment) by 35.1 % with respect to the previous season.

5. Conclusion

This paper has investigated the use of a TGT to improve engineering students' problem-solving abilities, teamwork skills, knowledge and attitudes. A TGT set up as the soccer '*Champions League*' has been introduced as part of the tutorials of four modules. The tournament could have also taken the form of any competition that would be engaging for particular student cohorts. More than 100 engineering undergraduates from multiple backgrounds have been exposed to the intervention. Students have shown to be very focused and participative in matches and no less importantly, to have enjoyed themselves. The success of the tournament in promoting deep thinking and in engaging students has been confirmed by students' feedback and by results in end-of-semester examinations.

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Supporting education and learning with game design elements

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Abstract

A phenomenon popularly known as gamification refers to the application of game design elements in non-game contexts with the goal of improving user engagement with the service. In recent years, it has garnered much attention and found its way into the education area where problems with maintaining student motivation still persist within some educational systems. In this paper, we're presenting the results of the analysis of three "gamified" educational platforms and elaborate in what way they implement elements of game design to motivate and engage users. We use previously developed methodologies, for the purpose of one of the author's master's thesis, which combines Werbach and Hunter's game element hierarchy with Deci and Ryan's self-determination theory to offer insight in interaction of system components with basic psychological needs. Our goal is to show how digital systems are using elements of game design to support basic needs and to provide reference for the design of future systems in educational contexts.

Keywords: *education, e-learning, engagement, gamification, game elements, user experience*

1. Introduction

Some often perceive traditional educational systems as ineffective and boring [1], as unsuccessful in engaging students with the class curriculum, and as incapable of keeping them motivated throughout the duration of their schooling [2]-[4]. The reason for this might be lack of consideration of different learning styles and the preferred learning environments [5] of each individual, focusing instead on methods that some consider outdated and not in line with the needs of the technologically savvy students of today [4] [6]. On the other hand, games seem to inherently connect to good learning design [7] and so succeed where most educational systems fail. Realizing this, educators attempted to combine games and learning in the past, giving rise to "edutainment" software, in hopes of facilitating better learning and information retention with students. Unfortunately, early attempts were unsuccessful as they tried to sugar-coat the learning process with a game-like dressing while retaining the standard behaviorist approach to learning [5], relying on external motivators instead of intrinsic values inherent in the activity [6].

We learned from positive psychology that intrinsic motivation is the key to engagement, meaning that an activity is appealing because it agrees with our intrinsic values, because we find some enjoyment or personal satisfaction from engaging with it, and not because of some external gain [8]. It's evident from further research that games are almost perfect sources of intrinsic satisfaction as they fulfill basic human needs—autonomy, competence, and relatedness—and thus represent optimal learning environments [9]-[11].

Researchers from the human-computer interaction field also observed the value of intrinsic motivation inherent in games and explored how they could produce more enjoyable learning environments [12] [13], including more enjoyable user interfaces [13] [14]. All of this inevitably contributed to the advent of gamification, a relatively new concept defined as the use of design elements characteristic for games in non-game contexts [15] with the goal of improving user engagement [16]. At its core, gamification is not concerned with the creation of games but with the design of game experiences using game design elements and techniques to improve the overall experience [6] [15].

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Gamification garnered much interest in the marketing world as a new way to promote businesses and products and it soon spread to other fields like education, health, or social good. However, at the same time, people in the gaming industry voiced their concerns that gamification misrepresents and simplifies games and game design [17] or that it might lead to user exploitation [18]. Regardless, inquiry in practical application of gamification in education has showed promising results [1] [2] [5] [19] [20], both in physical and digital environments, but only under careful consideration of educational challenges [3], students' needs [5], existing intrinsic rewards [18], available supplemental technology [1], and other context-specific questions [21].

This section covered some background about games and education to help to frame the context for gamification and our work. The next chapter includes an explanation of our research methodology and the models used to analyze Codecademy [22], Duolingo [23], and Khan Academy [24] educational platforms that implement game elements to facilitate different learning experiences. Afterwards, we present the analysis of each platform as per Werbach's and Hunter's hierarchy in relation to Deci's and Ryan's basic psychological needs. Finally, we discuss the implications and possible future work.

2. Research method and objective

Considering how gamification draws from game design and psychology to engage users, and considering the criticism it received based on its superficiality and lack of value for the user, we wanted to examine some of the educational platforms that employ game design elements to modify user experience and see whether the designs suggest the presence of depth and value and whether they might support basic human needs [25]. We're hoping the findings from this analysis can contribute to the body of knowledge related to gamification phenomena, particularly for educational purposes. It could support teachers and university administration to evaluate available solutions, and it could support designers in their design of future gamification platforms within an educational context.

For this endeavor, we selected Werbach's and Hunter's hierarchy of elements [26] to aid us with identification of game elements implemented on each platform. Other models exist [1] [2] [4] [5] [20], but they're developed within educational context and might not be applicable for the analysis of gamification platforms outside the educational context or might not include game elements occurring outside the educational context.

In our previous work [27], we examined gamified platforms across various fields using this model, so for the sake of consistency and advancement of our research, we've opted to use the Werbach/ Hunter model again due to its generalized structure. Admittedly, this model includes higher degrees of element abstraction not clearly defined by the model's authors, but we believe that once we identify lower-level elements, we can account for the presence of higher levels of abstraction, depending on component use and which dynamic or mechanic it contributes to.

Since intrinsic motivation is a frequent subject in gamification literature, we wanted to include a model that will help us identify how each platform may support basic human needs: autonomy, competence, and relatedness. To this end, we included Deci's and Ryan's self-determination theory and their definitions of each need [9] [10] [25] as a point of reference in our analysis. In regard to autonomy, we looked at how much control users have over the course direction and material selection and whether there are elements forcing users to participate, offering interesting choices, and opportunities for users to express themselves. Competence need is straightforward so we looked for clear goals, appropriate challenges and opportunities to demonstrate skills, and progression feedback that's clear and readily available. For the relatedness need, we looked for a way to connect with the community of interest, opportunities to interact with other users, and an underlying purpose or a theme.

Using the hierarchy of elements, we identified basic game elements over three platforms and examined their relationships before extrapolating conclusions about how features of each platform work toward satisfying the needs of autonomy, competence, and relatedness. We analyzed Codecademy, Duolingo, and Khan Academy platforms after an initial period during which we introduced ourselves to the system and its components through active use of each platform's features. We recognize there are other gamified educational platforms, but for the scope of this paper, we had to narrow our selection, so we opted for the more popular platforms that cover different topics.

3. Results and analysis

In this chapter we examine the three platforms by analyzing in what way they seem to support autonomy, competence, and relatedness, and reflect upon identified elements presented in **Table 1** and their role in fulfillment of those needs. Discussion of implications and drawn conclusions follows this section.

Table 1 - Identified game elements according to the Werbach/ Hunter hierarchy.

PLATFORMS / ELEMENTS	**Codecademy**	**Duolingo**	**Khan Academy**
DYNAMICS			
Constraints	✓	✓	✓
Emotions	✓	✓	✓
Narrative	✓		✓
Progression	✓	✓	✓
Relationships	✓	✓	✓
MECHANICS			
Challenges	✓	✓	✓
Chance			
Competition			
Cooperation		✓	
Feedback	✓	✓	✓
Resource Acquisition		✓	✓
Rewards	✓	✓	✓
Transactions			
Turns			
Win States			
COMPONENTS			
Achievements	✓		✓
Avatars			✓
Badges	✓	✓	✓
Boss Fights	✓	✓	✓
Collections	✓	✓	✓
Combat		✓	
Content Unlocking		✓	✓
Gifting		✓	
Leaderboards		✓	
Levels	✓	✓	
Points	✓	✓	✓
Quests	✓	✓	✓
Social Graphs		✓	
Teams		✓	
Virtual Goods		✓	✓

3.1.Codecademy

Codecademy [22] is an online educational platform where 24 million users are learning how to build websites and program in languages like Python and Ruby [28]. Codecademy offers guided courses and short introductory tutorials in order to make coding available to anyone [29].

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When it comes to autonomy, users can take one or more courses they're interested in and choose them based on complexity and the estimated course duration. Users can skip previously mastered lessons and work at their own pace toward course completion, closing and resuming sessions as they want. The system will pick up where they left off. However, lessons have direct instructions on what to do, which might be detrimental to user autonomy and often prevents users from advancing until they enter exactly the right piece of code, which can occasionally lead to frustration; unclear feedback of error messages might intensify it further. Codecademy tries to balance this with instances where users can be creative in task execution or add some personalization to their projects in the form of text and images. It's also worth mentioning that some of the lessons incorporate a storytelling approach in order give context to the task and to relate how acquired skills might be usable in real-world situations.

Codecademy supports competence in several ways. Lessons gradually introduce new concepts, and each unit usually ends with a review, requiring users to demonstrate understanding of introduced material. Users receive badges at the end of each unit to mark their progress and get a sense of completion. There are other badges for secret achievements such as complimenting users for regular daily attendance or for completing a number of exercises, but these are of limited variety. Codecademy implies levels through a number of completed skills and also tracks users' overall progress in this way. Earned points track how many lessons users complete throughout all attended courses, but the display has no context and might not mean much to a user apart from the message boards where they indicate status of some sort. There's no strong way to demonstrate mastery after completion of any course. Users can access Codebit Editor to practice building a website outside of premade courses or to browse other users' codebits, but this seems like an afterthought and an unused opportunity to additionally engage students, as Duolingo does with document translation (more on that below).

Relatedness support rests upon the premise of the social benefit arising from educating people how to program and upon the integrated message boards where users can help each other out and show mutual appreciation for relevant contributions through the up-/down-voting mechanism.

3.2. Duolingo

Duolingo [23] is an online crowd-sourced text translation and language-learning platform. It launched in 2011 and it has gathered 20 million active users so far [30]. Users can complete lessons appropriate to their language skill level and track personal progress while accumulating points, badges, and virtual currency.

Duolingo supports autonomy by giving users control over the learning sessions and allowing them to experience agency in this way. Users can set personal daily goals, learn at their own pace, choose what documents they want to work on translating, buy power-ups, or apply to participate in a language course incubator. Even practice exercises allow a certain degree of freedom when translating sentences as the system often accepts more than one right answer. Finally, there's no direct source of pressure, and participation remains volitional throughout. However, the daily streak counter might generate feelings of stress and required participation.

Users can demonstrate competence in various ways. Duolingo offers lessons ranging from beginner to intermediate while a detailed map of language skill "quests" clearly communicates to each user where they are and what the next step is. Most importantly, advanced users have an option to skip basics by taking an assessment test at registration. For their activities, users win experience points that count toward their progression of the chosen language's skill level. Points also influence leaderboard position in relation to users' friends' positions. Badges offer closure after each completed unit while also reminding users what skills they need to practice so the associated badge doesn't begin to fade over time. A decreasing bar next to each badge indicates a loss of ability. After a user completes a lesson, advancing content will unlock gradually, and users will periodically encounter a checkpoint test they must successfully complete in order to advance. Moreover, participating in setting up a new course also allows a user to demonstrate competence and language mastery. Lastly, in the document translation section users can advance through various tiers and get a better evaluation of their skills through peer feedback.

Social graphs that give users the means to follow each other or attract followers of their own and the ability to engage in personal communication through profile walls support relatedness. Duolingo allows skilled users to work in teams on translating documents from one language to another and so make a lasting impact by contributing to a greater social goal [31]. Users can choose to join or form teams to work on documents they share interest in. Duolingo implements a gifting mechanic, allows users to give lingots, a virtual currency specific to the platform, to users whose comments they consider especially instructional, amusing, or otherwise helpful. In this way users can show appreciation and acknowledgment of their peers.

3.3. Khan Academy

Khan Academy [24] is an educational platform that provides learning materials covering a variety of subjects including math, science, programming, and history. Salman Khan created the academy in 2006 with the goal of providing free education through video materials, but it has grown beyond that since.

As with the other two platforms, autonomy rests upon voluntary participation and a willingness to learn. – There’s no observable mechanism to generate pressure, and the user has complete control over how to approach and engage with the selected subject material. Everything occurs in a safe and supportive environment that adapts to a user’s needs using special algorithms [32] and makes each choice meaningful in this way. Also, users can express themselves through evolving avatars, communicating their own progression for the most part, and choose what behaviors and preferences to demonstrate through a variety of challenges at their disposal.

Badges and accumulated points primarily support competence. Badges group from common to legendary (with a special category reserved for Khan Academy employees), describing various accomplishments and different levels of competence (apprentice, journeyman, and artisan) and investment in various subjects, progressing from beginner learner to really invested learner. Users can undertake challenges to test and improve their skills (from “needs practice” to “mastered” level) and earn points, although practicing what one has already mastered grants fewer points than mastering new skills. Challenges are short and gratifying, and the site optimizes them for a user’s skill level to ensure adequate progression of difficulty and skill development. There’s plenty of other feedback about performance, including bonus points for each correct answer, skill progress made, or suggestion to what skills need improvement. Points are for user progression and unlocking of new content. Finally, one can demonstrate competence by coaching others, suggesting videos and tests or tracking a student’s skill progress through an interface that visually represents relevant student data.

For most users, a unified thematic approach primarily supports relatedness. Grounded in distribution of scientific learning materials, Khan Academy uses thematic icons and keywords for its badges and points in an effort to achieve better immersion. Users can participate on the discussion boards, but for those in coaching roles, relatedness extends into a more personal sphere so they can keep close track on student activities and progress, make recommendations, and feel personal responsibility. Again, social context and personal values play a big role in recognizing Khan Academy’s inherent purpose, which is to have users participate in badge-awarding behaviors and activities like exploring topics, watching videos, or developing new skills.

4. Discussion and future research

The foremost benefit these analyzed platforms have when compared to traditional education systems is that their use is primarily voluntary and dependent on the users’ needs or desire to learn. Users are free to explore materials they find relevant, attend courses of personal interest, and use them at their own pace and for as long as they wish. Most important is the lack of an authority figure, as in traditional education, because this alleviates pressure and puts the system in the role of a personalized and unobtrusive teacher, allowing the user to experiment, fail, and learn from his or her own mistakes [20].

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Users meet with challenges in the form of achievements and quests they can choose from that clearly define their short-term goals and supply relevant feedback in the form of points, levels, and badges in order to communicate progress toward the goal. Through implementation of a social component, these platforms allow users to connect with a like-minded communal area where they can help each other out, receive acknowledgement, or contribute toward some greater goal such as translating Web documents or coaching others.

From this analysis, it's evident some support of basic needs is present, although in varying degrees and through different use of game elements. We feel confident these platforms aren't as superficial as critics feared, but we admit there are areas designers might want to improve in future iterations to provide a more fulfilling learning environment. Our work is limited since this is a theoretical analysis of a delivered solution, performed without insight into design process and design decisions that might not adequately reflect the real degree to which basic needs are satisfied or whether users feel more motivated to engage in this type of education on their own on a regular basis. However, we'd like to point out a couple of design elements each platform stood out in.

Codecademy has done well to provide real-world examples of possible applications of codes developed during exercises by wrapping them in a narrative in order to bring the programming mindset closer to first-time programmers. Another interesting thing is its programming environment users can work in outside the class and apply their skills while receiving immediate feedback for each change in the code through a visual interpreter.

Duolingo is praiseworthy for offering a variety of acceptable solutions to text translations since sometimes-incoherent sentences require users to apply common sense along with the gained skills to convey the real message that might be incorrect in literal translation. Another point goes for the teamwork implementation as it offers the "end-game" users to continue practicing while also making a social contribution.

Khan Academy stands out for its implementation of algorithms through which the system adapts to a user's skill level and ensures challenges are in line with the user's needs. Another interesting feature is the way in which the system encourages advancement by "closing" already mastered skills so that the users don't cheat themselves by acquiring points and badges through practice of already mastered skills.

Since this is an ongoing research project, in the next phases, we'd like to research gamification artifacts from the user perspective. We'd inspect what the users' attitudes are toward gamification platforms in education, the factors influencing the use of artifacts, how users' social context relates to the platform usage and demonstrated behavior, and if non-gamified educational platforms offer equivalent support for basic needs' satisfaction.

Another area for exploration is concerned with the attitude and the actual use of gamification platforms within official educational structures. To do so, we could use the following theoretical frameworks: use the technology acceptance model [33] [34] and the model of information system success [35] to analyze user attitude toward gamification systems. Use socio-cognitive theory [36] and activity theory [37] to develop inquiries leading us toward deeper understanding of the phenomena of gamification. By doing so, we could research correlations of social and cognitive factors contributing to usage, the impact and role of the instruments (tools), the way in which community shapes behavior, what type of rules would encourage usage, and what types of division of labor to mobilize.

5. Conclusion

The goal of this work was to examine whether to consider educational platforms employing game design elements to fulfill basic human needs defined in self-determination theory [8] [9], or whether such implementations are superficial and lacking value for the user [17] [18]. To this end, we presented case studies of three popular platforms and elaborated how design elements of each might satisfy a user's basic needs of autonomy, competence, and relatedness [8] [9].

We would like to point out how each gamified platform seems to have necessary qualifications to support intrinsic motivation required for healthy user engagement. Gamification can't solve problems inherent in the educational system such as inadequate teaching skills or poor selection of class material [2] [21]. For this reason, we must approach the design of gamified systems, especially in education, with consideration of student needs and the challenges we're facing before we start to design systems for learning.

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Professional skills

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Comparative Teamwork Skill Development in Different Engineering Topics

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Abstract

Personal skills, like team behaviour, are definitely important outcomes of engineering courses. Team behaviour could change for the same person if the work frame changes or even if the team members change. This paper presents a case study of teamwork skill development within the scope of fundamentals of engineering topics in electronics engineering curricula. The aim of the paper is to compare team behaviour of individuals when facing teamwork within two different engineering courses. 54 students of the second year of a four-year degree in Electronics Engineering participated in an experience of teamwork skill development. The same set students took a course on Engineering Thermodynamics and also a course on Theory of Circuits. Both courses involved teamwork skill, though in different approaches and assessment. A rubric, intended to assess teamwork, was developed for the supervision of the teams and individuals with the requisite of being easy to understand by the students and short time consuming to fill it. Analysis of student's response is presented. Correlation between teamwork performance and learning results is also presented. Teacher's perception of the experience was obtained by means of personal interviews.

Keywords: *Teamwork, Theory of Circuits, Engineering Thermodynamics.*

1. Introduction

At present, most of science and/or engineering programs at high schools and universities describe what the students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge, and behaviours that students acquire as they progress through the program to prepare graduates to attain the program educational objectives. Among the course components, the successful achievement of the scientific objectives is clearly a basic assessment of the technical work and a good demonstration of the student's level of understanding. However, other components, like team behaviours, are definitely important outcomes of the courses. Team behaviour could change for the same person if the work frame changes or even if the team members change. This paper focuses on teamwork. Teamwork is the student outcome that means the ability to function on multidisciplinary teams. Teamwork is one of the most frequent ability involved in recent engineering courses, and takes part of many student-based approaches to learning, such as active methods, cooperative learning or problem based learning. Some suggestions to help lecturers to implement teamwork could be found in references [1]-[7].

This paper presents a case study of teamwork skill development within the scope of fundamentals of engineering topics in electronics engineering curricula. The aim of the paper is to compare team behaviour of individuals when facing teamwork within two different engineering courses. 54 students of the second year of a four-year degree in Electronics Engineering participated in an experience of teamwork skill development. The same set students took a course on Engineering Thermodynamics and also a course on Theory of Circuits. Both courses involved teamwork skill, though in different approaches and assessment. A rubric, intended to assess teamwork, was developed for the supervision of the teams and individuals with the requisite of being easy to understand by the students and short time consuming to fill it. This work continues previous research of our group in teamwork skill development [8].

2. Rubric-Based Method to Assess Teamwork Skill in Energy Courses

The experience described in next paragraphs have been developed in topics belonging the third and fourth semesters of an eight-semester undergraduate program leading to a degree in Electronics and Control Engineering at the Higher Polytechnic School of the University of Burgos, Spain [9]. The set of first to fourth semesters are devoted to basic engineering sciences, and they are the same in any of the engineering degrees related to industry concerns (mechanics, electronics, control, industrial management, etc.) at the University of

Burgos. The aim is to give deep foundations in basic engineering sciences to allow the engineer to adapt to changing roles along his working life. All the modules are taught over a period of 14 weeks and involve four hours of timetable contact per week (2 classroom/theory hours, 2 seminar/laboratory hours), for a total workload of 6 ECTS credits. Some of the subjects involved in these basic engineering sciences are related to energy topics, in a broad sense, such as Engineering Thermodynamics, Fluid Mechanics Engineering, Electrical Engineering Fundamentals or Theory of Circuits. Some of the respective teachers belong to an innovation teaching group and collaborate frequently in implementing innovative teaching-learning experiences. As designed in the study plan, the students should acquire some general skills. Amongst these skills is the teamwork skill. This skill is assigned to most of the subjects of the study plan. However, the implementation of this skill is unbalanced, frequently limited to the aforementioned simple idea of giving three or four students something to do together. Two cases of application would be described, in the subjects of Theory of Circuits and Engineering Thermodynamics, respectively. Emphasis has been put on the explanation to students of the importance of this skill in his professional development. Teams of 3-4 members have been constituted, and internal interdependence has been promoted amongst teammates. Team work has been used to the limit that every teacher has considered adequate to reach the learning outcomes of the subject and its own experience.

In the topic Engineering Thermodynamics (compulsory, 2nd year, 3rd semester), a structured problem based learning approach was adopted. This compulsory module aims to impart a fundamental knowledge on Thermodynamics and Heat Transfer, with a special focus on energy analysis of basic heat and work fluid processes. At the beginning of the course an open problem of industrial energy analysis is assigned to the students, following the PBL approach. The full details of the experience can be found in reference [10]. Three assessment criteria have been proposed: team reports, up to 30%; individual exams, up to 30%; and final team report, up to 40%. Then, it can be stated that the approach is strongly centred on teamwork (70%), while the individual assessment allows differentiation amongst team members.

Thus, in the topic Theory of Circuits (compulsory, 2nd year, 4th semester), the development of the activities of the students and its evaluation are distributed amongst individuals exams along the course (30%), final individual exam (40%) and team laboratory practice (30%). This last activity involves the laboratory work (sine stationary circuits, three-phase systems, etc.), the writing of laboratory reports and team-exams. We can say that the approach of the topic is a traditional one, based on individual learning by means of lectures and exams, while the teamwork plays a complementary role, both in workload hours and its assessment (30%).

During the academic year 2013/2014, both study modules have been taught. 54 students participated. Student attitudes and perceptions to this assessment approach were surveyed through the rubric shown in Table 1. At the end of the semester, every team member filled the rubric evaluating himself and the rest of members. There exist several literature references on the use of rubrics in engineering education [11]-[13]. The authors developed a rubric to evaluate five elements of team work: (i) Contribution to teamwork; (ii) Taking responsibility; (iii) Individual contribution outside of team meetings; (iv) Promotion of constructive team climate; (v) Response to conflict. The rubric is presented in Table 1.

Table 1. Rubric for ability to function in teams.

Definition: Teamwork is behaviors under the control of individual team members (effort they put into team tasks, their manner of interacting with others on team, and the quantity and quality of contributions they make to team discussions.)					
Instructions: Please rate YOURSELF & YOUR TEAM MEMBERS using the provided table. Please fill in the table below honestly, and as accurately as possible. Please use the following rating scale: 3-Excellent; 2-Good; 1-Needs improvement; 0-Unacceptable					
Level	**Description**	**Member 1**	**Member 2**	**Member 3**	**Member 4**
1 Contribution to teamwork					
3	Collect and present to the team a great deal of relevant information; offer well-developed and clearly expressed ideas directly related to the group's purpose				
2	Collect basic, useful information related to the project and occasionally offer useful ideas to meet the team's needs.				
1	Collect information when asked for and try to offer some ideas, but they are not well developed, or not clearly expressed, to meet team's needs.				
0	Fail to collect any relevant information or give useful suggestions to address team's needs.				
2 Taking responsibility					
3	Perform all assigned tasks very effectively, attend all				

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	team meetings, participate enthusiastically, and remain very reliable.				
2	Perform all assigned tasks, attend team meetings regularly, and usually participate effectively and reliably.				
1	Perform assigned tasks but needs many reminders, attend meetings regularly but generally do not say anything constructive, or eventually expect others to do his/her work.				
0	Fail to perform assigned tasks, often miss meetings, do not have any constructive contribution when present, or usually rely on others to do the work.				
3 Individual contribution outside of team meetings					
3	Completes all assigned tasks by deadline; work accomplished is thorough, comprehensive, and advances the project. Proactively helps other team members complete their assigned tasks to a similar level of excellence.				
2	Completes all assigned tasks by deadline; work accomplished is thorough, comprehensive, and advances the project.				
1	Completes all assigned tasks by deadline.				
0	Frequently, does not complete the assigned tasks by deadline				
4 Promotion of constructive team climate					
3	Always listen to others and their ideas, help them develop their ideas while giving them full credit, and always help the team to reach a fair decision.				
2	Generally listen to others' points of view, always use appropriate and respectful language, and try to make a definite effort to understand others.				
1	Usually do much of the talking, do not pay much attention when others talk, but avoid personal attacks and put-downs although sometimes patronizing.				
0	Often argue with team mates, do not let anyone else talk, have occasional personal attacks and "put-downs", want to have things done his/her way, or do not listen to alternate approaches.				
5 Response to conflict					
3	Addresses destructive conflict directly and constructively, helping to manage/resolve it in a way that strengthens overall team cohesiveness and future effectiveness.				
2	Identifies and acknowledges conflict and stays engaged with it.				
1	Redirecting focus toward common ground, toward task at hand (away from conflict).				
0	Passively accepts alternate viewpoints/ideas/opinions. Doesn't accept confict solving				

3. Results and Discussion

No restriction was given by the respective teachers to form the teams, as they did not perform any previous test to fix any criteria based on previous knowledge of students. Then the teams were formed by the choice of students. To establish some comparison between both topics concerning student’s perception of teamwork skill, we had first to select those students who belonged to the same team in both topics. Only 3 teams of three members each were formed exactly by the same people in both topics. We found also 9 teams were at least two members were the same, but we discarded the use of such data because there would be some other reasons that could influence the behaviour of the students within the team.

Table 2 presents the average results of the perception test for the 3 teams, A, B and C. Students are numbered from 1 to 9. ET stands for Engineering Thermodynamics while TC does the same for Theory of Circuits. Rubric categories 1 to 5 correspond with definitions given in Table 1. Scoring values for every category and student are presented, as well as the average and standard deviation (StdDev) for every student.

Table 2. Results of the perception test given in Table 1 for the set of 3 teams.

Rubric category	Team A						Team B						Team C					
	ET			TC			ET			TC			ET			TC		
	1	2	3	1	2	3	4	5	6	4	5	6	7	8	9	7	8	9
1	2.0	2.8	2.0	3.0	2.7	2.0	3.0	2.3	2.3	3.0	3.0	3.0	2.3	2.0	3.0	2.7	2.0	3.0
2	2.8	2.8	2.8	3.0	2.3	2.0	3.0	2.8	2.8	3.0	3.0	3.0	2.3	2.0	3.0	2.7	1.7	3.0
3	2.3	2.5	2.3	2.7	2.7	2.0	2.8	2.3	2.3	1.7	1.7	2.0	2.3	2.3	3.0	1.7	2.3	2.7
4	2.8	3.0	2.8	3.0	3.0	2.7	2.3	2.5	2.5	2.5	3.0	3.0	2.5	2.3	2.5	2.0	2.3	2.3
5	2.8	2.8	2.8	3.0	3.0	2.7	2.5	2.8	2.8	2.7	2.7	2.7	2.0	2.5	2.8	3.0	2.7	2.7
Average	**2.5**	**2.8**	**2.5**	**2.9**	**2.7**	**2.3**	**2.7**	**2.5**	**2.5**	**2.6**	**2.7**	**2.7**	**2.3**	**2.2**	**2.9**	**2.4**	**2.2**	**2.7**
StdDev	**0.3**	**0.2**	**0.3**	**0.1**	**0.2**	**0.3**	**0.3**	**0.2**	**0.2**	**0.5**	**0.5**	**0.4**	**0.2**	**0.2**	**0.2**	**0.5**	**0.3**	**0.2**

Considering every rubric category, category 1, contribution to teamwork, the members contribute fairly to the teamwork. With respect to individuals, only two students received a score of 3.0 in both topics, while only one student received 2.0 twice. Only one student got a huge increase, from 2.0 to 3.0. We can conclude that attitude to teamwork is intrinsic in those students.

Related to question 2, taking responsibility, the average score is also high. Team B keeps almost the same high score in both topics, above 2.8. Then, students in this team were responsible in a very god manner. Team C presents a greater contrast between students 8 and 9, one showing a low scoring and the other the top scoring. In this case the responsibility fell on the second.

It can be observed that the category 3, individual contribution outside of team meetings, presents the lower value for the majority of students in all teams, revealing that, in both experiences, students do not give enough importance to the personal work compared to the work developed when the team meets. Only one student received the maximum 3.0 in this category. It shows the weakest feature of teams.

Question 4 deals with promotion of constructive team climate. This question obtained the highest value for team A (which shows high performance in this category), medium value for team B and the lowest value for team C, though always above 2.0. This team C seems to have had not a good team climate.

Response to conflict was the topic of question 5. Being taught the topics in consecutive semesters, and being free the students to form the teams, it could be expected high performance in this category, as occur. If conflict would have happened, teams would not have kept the same composition. Scoring is always grater then 2.5, with only one exception 2.0.

The students declared the best performance concerning the promotion of good team climate, probably due to the fact that they can work also in teams in other subjects within the study plan, presenting no dramatic interpersonal conflicts. The weakest performance is clearly the contribution of homework. Many reasons could influence this performance, as interest in the topic, or competition with homework of other subjects. Comparing average values for every student, there is no huge change between ET and TC topics. Some students score slightly higher, some others slightly lower. Changes in average values are within the standard deviation values, showing no remarkable influence of the topic on global teamwork behaviour.

With respect to the utility and easy-of-use of the rubric, students show no query about it, all students fulfilled it. It took no more than 4 minutes to keep it. Teacher's perception is that results cover sufficiently the scope of the competence as defined by the institution, and that no more complexity is needed to measure this critical skill.

4. Conclusion

This paper presents a case study of teamwork skill development within the scope of fundamentals of engineering topics in electronics engineering curricula. The aim of the paper is to compare team behavior of individuals when facing teamwork within two different engineering courses. The same set students took a course on Engineering Thermodynamics and also a course on Theory of Circuits. Both courses involved teamwork skill, though in different approaches and assessment. Student attitudes and perceptions to this assessment approach were surveyed through a rubric including five categories. Results show that there is no huge change in student's perception between both topics. Some students score slightly higher, some others slightly lower. Changes in average values are within the standard deviation values, showing no remarkable influence of the topic on global teamwork behaviour. Moreover, the rubric seems to be a very useful and simple way to instruct teams about how to improve their performance beyond academic courses.

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Systematic Method for Teaching Engineering Working Life Skills

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Abstract

We present and demonstrate a systematic method for teaching working life skills to engineering students. An intended learning outcome (ILO) based approach is used for curriculum definition and development. The teaching of working life skills is implemented coherently using special courses and integrated learning in the technology courses. The specialized courses cover engineering basics, group work and product development during the first year of studies, and further courses on project and engineering skill topics targeted towards the implementation of a large-scale multidisciplinary development project in the 4^{th} – 5^{th} study year. Integrated learning is used because there is not enough space in our educational programs for multiple special courses solely for teaching working life skills. Moreover, there is no reason to fully separate working life skills from the technical context provided in technological courses. We split the engineering profession into smaller subcomponents which can be further defined as learning outcomes for working-life skills. These subcomponents are analyzed in the context of the very turbulent and globalized working environment of the engineering profession in the future. We conclude the paper by presenting our experiences gained in implementing the teaching of working life skills.

Keywords: *Working life skills, Soft skills, Employability skills*

1. Introduction

In the Finnish Information Technology sector working life readiness has traditionally been considered synonymous to having outstanding substance in your technical field. There is no tradition at universities for systematically teaching everyday working life skills like efficient team work, project management, and communication and presentation skills. It has been thought that the recruits will learn these skills in the (big) companies, but this is not the case anymore. Employable means way more than just excellence in IT; the companies are not ready to teach new recruits the skills that are actually needed at a job. Engineering working life skills, or soft skills, are required in the global changing environment of working life and technology. Some of the necessary working life skills, such as managing or working in a project, can be learned in courses specifically focusing on this. Selected competences, such as team working and presentation skills, can be naturally integrated to courses targeting specific technological competences. Some basic working life requirements, such as keeping deadlines and arriving to meetings on time, may even be affected negatively during studies in an academic environment unless the importance of these working habits are recognized. Engineering working life skills are essential to a graduate in order to get a job. The meaning of employability varies between profession, between phases of a professional career and the job specific competence requirements. Job specific functional skills and competencies are essential, but they are highly context specific. Hard technical skills are not enough for making a graduate employable. Virtually all jobs have requirements for these skills, like teamwork and communication skills as well as problem solving skills. These skills are commonly not context specific. In the University of Turku the engineering students are commonly employed before graduation, which may slow down the final graduation. Part time working during the final stage of studies will often increase the students’ motivation in important working life skills.

Nilsson [1] shows in his study that engineering graduates have expectations that are not completely consistent with current university practices. According to Nilsson the graduated engineers consider higher education programs to be too focused on hard skills like knowledge of IT and computer programming. In an engineering graduate’s view developing soft employment skills, that is, building general educational foundation for lifelong learning is important. Required specific professional competencies will be acquired and developed further in the workplace through a person’s professional career. The importance of hard technical vocational skills in employability is decreasing. Yuzainee et al. [2] showed in their study among Malaysian engineering employers that the most important competence for the entry-level engineer is communication skills. The engineering education curriculum is traditionally based on degree level intended learning outcomes, which are transferred into specific courses. Certain working life skills, such as project management, are taught on specific courses just

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like hard technical competencies. The curriculum may have included also limited short courses on technical writing or on basic presentation skills. This is not an effective way for the students to truly acquire the required skills. Most of the learning of working life skills can be integrated in existing courses. Idrus [3] studied issues in integrating soft skills in the technical courses by the Malaysian lecturers. The main issues were students' attitude in the classroom, limited time to cover the syllabus and large number of students in the classrooms. Students' attitudes on soft skills are likely heavily influenced by lecturers' attitudes. Motivation is required for both parties. Existing learning targets seldom include any working life skills. The target for the lecturer is to achieve optimal learning of the hard technical topics defined in course syllabus and the same applies to students. Some students are naturally talented team workers or presenters, and motivating these students is easy. They will learn the required skills efficiently. Students having issues with podium panic or teamwork are the most difficult ones to motivate for learning the important skills. These students must step away from their comfort zone in order to get practice on the required skills. Proper motivation is required from the lecturer to understand that it is a lot easier to learn and practice these skills with peer students instead of learning-by-doing by presenting something to important customers in a new job.

This paper presents our method of systematically recognizing important working life skills and how to formalize them into intended learning outcomes. We present two ways of teaching the skills: on special working life skill courses and as integrated content in technical courses. In chapter 5 we present our implementation and discuss the assessment issues. As an example we present survey results of the course "Introduction to Engineering". The results indicate good results on learning and understanding the importance of working life skills already during the first year of studies, thus enabling motivated and efficient learning of skills throughout the five year studies.

2. IT Engineering Working Life Skills

Required working life skills have been analyzed in many studies during last years. Most of the studies indicate the need for quite similar types of competencies. The need of these skills is not limited to engineering education. Most of the working life skills are context-independent. Some jobs have naturally specific requirements for certain soft skills; however, the variation is remarkably lower than in hard technical job-specific skills. ABET, an accrediting agency for academic programs in the disciplines of applied science, computing, engineering, and engineering technology in United States, has listed 11 general student outcomes as their accreditation criterion [4]. The following 7 out of the 11 outcomes can be classified as engineering working life skills:

- an ability to function in multidisciplinary teams
- an ability to identify, formulate, and solve engineering problems
- an understanding of professional and ethical responsibility
- an ability to communicate effectively
- the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
- a recognition of the need for, and an ability to engage in life-long learning
- a knowledge of contemporary issues

Yuzaine et al. [2] have analyzed and prioritized the most important skills among entry-level engineers seen by Malaysian employers. Yuzaine et al. show the most important skill for employability to be **communication skills**. Yuzaine is referring to verbal spoken communication skills including listening skills. We spend 70% of our wake time in some mode of communication, which comprises of 10% writing, 15% reading, 30% talking and 45% listening [5][6]. All of these skills are essential in engineering work. Written communication skills [7] include skills for writing technical reports and instructions that are easy to understand by co-workers with or without engineering background. *Visual communication skills* in drawings, diagrams and symbolic pictures are important for most engineers. Both oral and written *presentation skills* are crucial in most engineering jobs.

Team working and interpersonal skills are essential in today's working ambient. *Understanding own role* is a basic requirement for an engineer in order to function effectively as an individual in the team. Engineering teams are often multinational requiring *global cultural understanding* including communication skills and understanding *international non-perfect English language with different accents*. Basic *leadership and managerial skills* are well-known skill requirements for some engineers, however understanding the role of the *employee* and his *organizational citizenship skills* are needed by all graduate engineers.

Professionalism is needed in all engineering work. Professionalism includes understanding of social, cultural, global and environmental responsibilities as well as commitment to professional and ethical responsibilities [8]. Success in academic education is measured in credits and grades. Credits can be optimized by passing the exams with minimum effort, grades measure too often the students' ability to answer the questions during a few hour exam. Professionalism requirements for an engineer at work are quite different. Punctuality in arriving to agreed meetings and keeping the deadlines of the tasks are basic requirements. The tasks require often some new skills or knowledge. Success in these tasks requires professional understanding of the new knowledge, plain “pass the exam”-attitude will not help the engineer along the career. Also ethical and social responsibilities can be counted as a part of professional skills.

Problem solving, critical thinking and decision making skills are basic skills in almost any engineering work. *Innovation process* skills are essential for engineers. Stiwne and Jungert [9] show in their study among engineering graduates in Sweden that the graduates consider *problem solving and critical thinking* to be most important skills in the working life. In the study by Yuzaine et al. [2] problem solving and decision making was the 4th most important skill according to employers, clearly above hard technical competencies. In addition to engineering, problem solving skills are important for multiple other disciplines.

Lifelong learning has been recognized as critical in engineering for decades [10]. In today’s rapidly changing world in high technology engineering this requirement has become even more important.

Understanding business processes and a person’s own role in them is a basic requirement for an engineer working in an organization. Today’s turbulent global ambient requires engineers to be able to function in a rapidly changing and insecure environment.

At University of Turku we have defined the IT engineering profession as consisting of three categories of skills, which are somewhat overlapping. People skills describe a person’s ability to work with other people. People skills consist of communication skills, team working skills, interpersonal skills and ethics. Procedural skills are required for success in actual engineering work. Procedural skills include professionalism, project working and managing skills, problem solving skills and knowledge of basic business and innovation processes. Contextual skills include multidisciplinarity, the ability to understand, communicate and operate in a multidisciplinary team or working ambient with non-technical human centric aspects. IT society skills are also included in this group. The solution used in the University of Turku will be described in the next chapter.

3. Method

At University of Turku the degree level intended learning outcomes in engineering education are defined in an annual curriculum process shown in figure 1. A workgroup consisting of the heads of education at the department defines the degree level outcomes based on the experience and evaluation results of the previous curriculum. External stakeholders are strongly influencing some of the outcomes. Finland’s Ministry of Culture

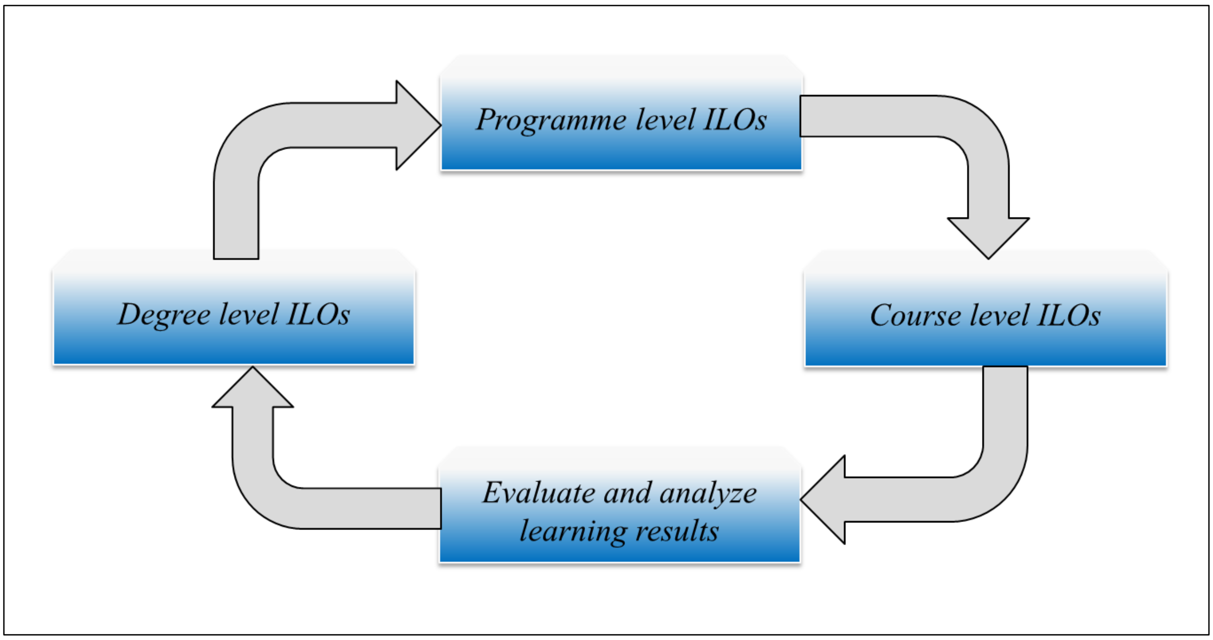

Figure 1. Annual curriculum process defining intended learning outcomes (ILOs) from degree level down to individual courses

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and Education regulates education and the national funding of it, this way affecting the strategy of the University and ultimately even the decision making process on the degree level outcomes to an extent. The CDIO organization has defined a number of outcomes in a framework utilized in our curriculum. Industry representatives have their requirements for employable engineers. Programme and course level outcomes are defined from the degree level outcomes in workgroups consisting of the teachers in department. The changing global ambient in our high technology field requires annual minor adjustments to outcomes in most of the courses. Major changes, such as a completely new course, are limited to a small number of courses per year in order to keep the process manageable.

The following intended learning outcomes were identified for working life skills in the Master degree level. Bachelor level outcomes are very similar, but the targeted skill and expertise level of the outcomes is lower there.

- Good **communication** skills including oral communication and oral presentation skills, written reports and written presentation, all taking into account the target audience in question and their ability to understand the communication from their technological and cultural background. In written communication, skills to produce highly understandable, clear and comprehensive texts (academic, technical, popular) in good English.
- Understanding **team dynamics** and **own role in a team**.
- Ability to work efficiently in a **multicultural and multidisciplinary team** consisting of technical and non-technical professionals.
- Understanding and committing to professional, social, cultural, global, environmental and ethical responsibilities (**professionalism**).
- Ability to comprehensively and widely obtain information while taking a critical attitude towards the information sources and the discovered information. Ability to distinguish between relevant and irrelevant information and to condense the information (producing an executive summary or a topical survey), and to properly refer to sources.
- Ability to apply the theoretical/technical knowledge learned in the degree into practice and into practical applications. Development of own expertise (**life-long learning**), ability to consider the field from a broad perspective.
- Ability to control the different tasks of a **project**, ability to take a responsible role in project work as a group member in an international multi-cultural setting. Ability to organize own work and also the work of others in the project, ability to **understand one’s own role** in the project.
- Ability for efficient **problem solving** in a project setting.
- Ability to creatively and efficiently solve problems in different situations and environments. Ability to identify different potential solutions and to choose the one that seems most feasible based on the available information.
- Understanding basics in **leadership and management** of people and the role of employee. Good organizational citizenship skills. Networking skills for building functional working life networks.
- Understanding basic **business processes** and own organizational role in them. Ability to understand and participate efficiently in **innovation processes**.
- Ability to operate efficiently in a global turbulent and **insecure ambient**.

Setting the degree level intended learning outcomes of traditional hard engineering skills into dedicated courses is quite straight forward; this is the base for traditional engineering education. Some of the engineering working life skills, such as basic project management, are suitable to be taught in a special course, but deep learning requires applying the learned theory in practice. This happens naturally in more advanced technical courses utilizing project structure. Dedicated courses are possible for only a limited selection of working life skills due to the tightness of our curriculum. Some studies show good results in integrating teaching of these skills in a single hard technical course [11]. At University of Turku we selected a combination. The teaching of working life skills starts during the first year with the course “Introduction to Engineering”, pushing the freshmen into basics in team working, problem solving and project management and forcing their own thinking closer to the engineering profession. Many skills, such as *professionalism*, should become a normal part of students’ working habits. This requires consistent learning throughout the 5 year long studies. Group works, presentations and special projects have been part of traditional engineering education. Recognizing and emphasizing the importance of these working life skills motivates the students to learn the skills and teachers to acknowledge these learning outcomes as an essential part of their technical course. A capstone project at the end of the studies, before the Master’s Thesis, requires applying most of the achieved working life skills into practice. The capstone projects are commonly multidisciplinary and are done in multicultural project teams. The capstone project caps the technical knowledge as well as the working life skills learned during the previous 5 years.

4. Implementation and evaluation

In this section we present the reform of Engineering Education at University of Turku and describe how the learning outcomes were connected to individual courses. The structure of our engineering education curriculum is presented in Figure 2. New students execute a working life skills starting package during the first year. The **Bachelor level** studies starts with a specific course “Introduction to Engineering”. The freshmen having very limited knowledge on any engineering work are combined randomly into teams and get engineering tasks to solve. This course follows a problem based approach for learning problem solving and team working in a project. The course also has lessons providing theoretical background on the same issues. During the second year of Bachelor studies the students also participate in a course on basics of product and service businesses. Our Bachelor degree curriculum includes several short courses on written and oral Finnish, Swedish and English languages. Most of these courses are integrated with technical courses. Some courses have a few lessons lectured in Swedish language; some courses are lectured totally in English. These languages are used also in assignments and they are reviewed by both the language teacher and the technical subject teacher.

The “Working Life Skills” –module at **Master level** is divided in two sections. Compulsory course “Engineering Working Life Skills” provides basic skills required for all graduates in a global changing environment of working life and technology. These include skills for systematic engineering work and problem solving, how to work in a project and understanding the student’s own role in it. The course includes also basic understanding of business processes, innovation processes, the life cycle of a product, service or knowledge and the basics for sustainable development. The student is aware of professional and ethical responsibilities in his/her duties as well as the effects in the society. The second part of the “Working Life Skills” module at Master level can be selected according to the student’s orientation from topics in advanced project management, business management or operating in an international environment.

Most of the master level courses include team working, project working, written and oral communication and student presentations. **Integrating the learning** of these skills in technical courses is very efficient. Presently these important working life skills are not included in the technical course intended learning outcomes. However, the importance of these skills as a part of degree level learning outcomes is emphasized. Including these skills in the technical course outcomes would require assessment of these skills as a part of the course grade. This problem will be discussed in the next section.

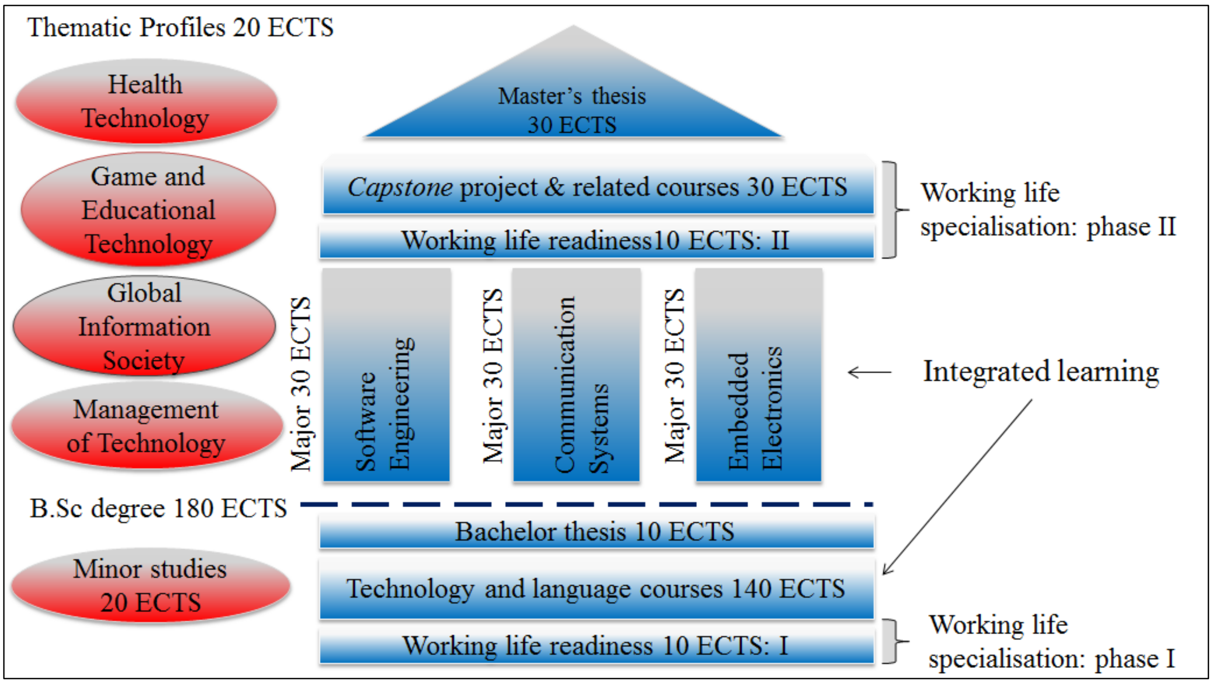

Figure 2. Engineering Education structure at the University of Turku

At the end of the studies, before the Master’s Thesis, a **capstone project** is carried out. It is an advanced, developmental project that corresponds by volume to several Master’s Theses. In a capstone project students learn to work with multidisciplinary engineering problems in a multicultural environment. The capstone project is essential for learning as it pushes the students to apply the learned working life skills in a practical real life project.

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4.1. Assessment issues

Assessment of the working life skills is difficult. As employers consider these skills to be as important as “hard” technical skills, they would appreciate direct grading of these skills in order to help in evaluating a number of candidates. Fair judgment of these skills would be straight forward at the end of a specific working life skill course. However, working life skills are developing throughout our five year curriculum and a grade based on the early study years may not indicate reliably the actual reached skills of the graduated candidate. Also, only a few of the skills can be taught on a specific course. In integrated learning the working life skills should be included in the technical course’s intended learning outcomes. If this is the case, reaching also these outcomes should be evaluated in the course grade. This would mix skills of a very different nature; employers would not be able to analyze if the applicant is talented in oral presentation skills or has a deep technical knowledge on a specific subject. The working life skills should be included as a separate set of outcomes that have only a minor, if any, effect on the “hard” technical course grading.

Assessment has also other functions beside the course grade. Assessment processes provide important information on the learning outcomes and a feedback process has positive impact on student’s learning. Assessment can be based on e.g. multisource feedback, peer and self-evaluation and rubrics [10]. Students’ active involvement in their own assessment forces them to think and analyze their own learning, improving their metacognitive skills. In addition to helping students’ learning in the university, this has a positive impact on another working life skill - lifelong learning. The target level of the working life skills generates another problem. All engineers are not the same, some are naturally talented in some of the skills, and some are talented in other skills. Different jobs have different skill requirements. Basic level of these skills is required in virtually any job; some engineering jobs may require very high skills on e.g. oral communication. Assessment, including self-assessment, is beneficial for the student building a career based on own personal talents.

4.2. Experiences

Our first experiences on integrated working life skills teaching are promising. None of the participating students have yet passed their whole 5 year studies using the new method for integrated working life skill learning as we are only two years into the new reformed curriculum. Pushing the first year freshmen directly to hands-on engineering action has shown to be very positive for most of the students. This is a vital part in proceeding towards engineering identity and profession during the coming years of studies. Integrated working life skill teaching in the technical courses requires some changes in the lecturers’ way of operation. Commonly a small set of teachers take active and enthusiastic roles in taking the new ideas to practice. So far the new method emphasizing working life skills has been in use in a limited number of courses only. This is already enough for the process to repeat working life skill learning from semester to semester throughout the curriculum. Taking the new approach into all courses will still take several years. The self-improving nature of a process through the feedback is essential for any new method. Motivation of students and teachers is the key for success in changing the working habits. Emphasizing the need for working life skills throughout the studies starting immediately at the first year motivates the students. Applying the skills in multiple projects, group works, oral presentations and written reports helps the student in understanding the need for working life skills especially if the work is connected to interesting technical content.

Some of the students, typically the students that have the strongest need for learning these skills, are quite reluctant for learning non-technical engineering working life skills. Stepping out of one’s own comfort zone is difficult. Leaning these skills and getting experience with peer students is easier than as a professional engineer in a working ambient. Classroom ambient with positive approach on learning and accepting failures is crucial for the students. As an example, experience has shown a remarkable improvement in a student’s presentation skills after only two compulsory personal oral presentations. Some students may have exceptional issues with e.g. podium panic requiring strong motivation. Pushing this kind of a student too heavily could end up with a lifelong trauma. How far to motivate and how far to push a student is a difficult question. Teacher should never diagnose students on these issues, that task has to be left for medical professionals. This type of a medical condition may seriously limit a student’s career possibilities.

The **Introduction to Engineering** course presented in the previous chapter is targeted for students just starting the engineering studies. The course takes place in the first teaching period of the first year. Instead of spending the first years learning theory from books, the students face hands-on engineering problems immediately after selecting the engineering career. The engineering tasks and team work are quite challenging for freshmen. A survey among the 62 students of the 2014 course received 58 answers (94 %). One of the first questions measured student motivation: “did you have fun with the tasks of the course”. 74 % replied they had “a lot of fun” or “quite fun”. 5 % had “not much fun” and 0 % “not fun at all”. In the team working skills 69 % of the students answered they learned or learned and learned and understood the meaning of teamwork. 64 % of the students answered similarly on the skill "Accepting errors and insecurity". These skills are defined as learning outcomes of graduated student after 5 years studies. Achieving these outcomes can be analyzed at the end of the studies; this course is only a sneak peek on the engineering profession.

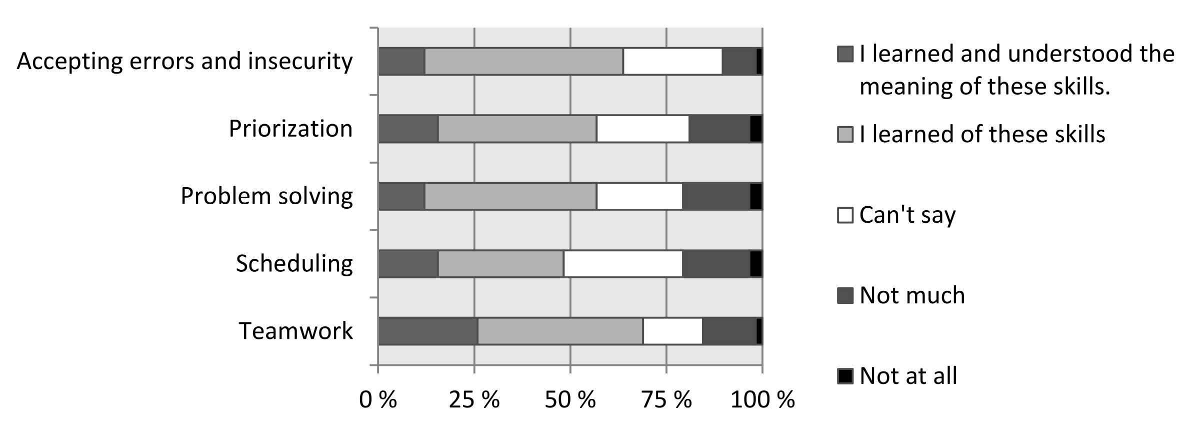

Figure 3. Results of the survey questions "Did you learn on…" from the students of the course *Introduction to Engineering 2014*. n=58

The survey included several open-ended questions providing good information on reaching the targeted outcomes. Students clearly understood the importance of **communication** in a team work:

"Team work is strongly dependent on communication"
"I learned we have to listen to others and seek together for the solutions"
"I learned how to listen. Usually I talk too much and take control of the situation. Now I learned to give space for persons with better knowledge. I learned how to work with different type of people."

Students understood the basic issues on **team working**:

"I learned that working in a team requires sometimes a lot of effort."
"I learned that a working team is not self-evident. Also splitting the task was more challenging than I expected."
"I learned that working in a team requires accepting compromises."

The first year students were surprisingly capable of **self-reflection**. Some students found new **leadership skills** in themselves. Many of the students understood well their **role in the team**:

"I learned how of organize tasks. We organized well and were ready long before others and won the first competition easily"
"I have not considered myself as a social person. During the team work I found new side of myself and the team work was easy."
"I learned I like to manage things. Half accidentally I got the team leader task. I learned I can control thing surprisingly well"
"I was really active in the team. I found certain leadership skills on myself that I was not aware of."
"I was sometimes quite a controlling person in a team; I would not have believed this side on myself."
"I can drive the team to the required result. Sometimes in imbroglio I managed the take the situation in control and got things running. In a rush I was sometimes too nervous."

Some students consider themselves as team workers instead of leaders. This self-reflection is important when planning how to direct the studies and what kind of engineering career one should target:

"I'm not much of a leader. I rather take orders than give them. I'm better in doing a single task at a time than taking care of everything. I need to improve my communication skills."
"Clearly I am not a leader."

One of the teams in this course did not perform well. Teacher intervention would have been required for this group during the group work. Recognizing the problems early enough is challenging as the written feedback comes after the course:

"Only thing I learned on the report writing tasks was that group works are dull and you can't trust anyone."
"In a group you a heavy command if fellows do not do their work. One should forbid all smart phones during the work. Can't trust anyone. Everybody is lazy."
"Don't trust people. There was only one beside me working actively, rest of the group was only watching."

The team work issues in these student answers represent a problem that is too common in the real working life. Recognizing this type of a problem early enough is essential for successful work in any organization. Solving this type of issues requires commonly intervention by a non-team member, typically by the superior or in the course by the teacher. Lack of individuals' **professionalism** may destroy the success possibilities of the whole

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team. These answers provide very valuable examples for the next year students, helping them to evaluate their own team's capabilities and ask for help if needed.

5. Conclusion

In this paper we presented our systematic method used in the University of Turku for identifying, teaching and assessing engineering working life skills. Teaching is based on a combination of specific courses and integration. First experiences are very promising. Language and communication learning is inspiring when the topic is directly connected to interesting technical subjects. New students are highly motivated to take a direct hands-on engineering course instead of spending a few years on learning theory before any actual engineering work. Survey results show that first year students achieve good understanding on the basic working life skills, enabling them to actively learn and apply the skills in suitable tasks on forthcoming technical courses. These tasks include group works, projects, report writing, oral presentations and many other topics. Most of the working life skill learning takes place on a side of a technical course as integrated learning. Structured recognition of these skills as intended learning outcomes is only the first step on this way. We still have a lot to do before all courses utilize their potential for teaching these important skills, and assessing them in a suitable way.

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Addressing the UK IT Skills Shortage: 'Tech Gold' Degrees

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Abstract

This paper will outline how a sector skills council chaired, employer-led design and development team, informed by wider employer consultation, has been working with curriculum experts from partner universities (including UWE,Bristol) to define the learning outcomes of most value to the IT and Telecom's sector and to develop and deliver degree programmes that develop the knowledge and the skills required to enable students to secure careers in the IT world and to help to address the UK IT skills shortage. The background to and the rationale for the initiative is given by way of context, followed by an account of the development, implementation and operation (at UWE) of the first of the e-skills/Tech Gold degree programs; the BSC(Hons) Information Technology Management for Business (ITMB). Evidence for the successes achieved by the programme in relation to performance and employability is presented and used as justification for the development, implementation and operation of a new UK-wide programme in Software Engineering; the BSc(Hons) Software Development for Business (SDfB).

Keywords: *IT Skills Shortage, Industry-Led Degrees, Collaborative Curriculum Development*

1. The UK IT Skills Shortage

Like most leading nations, the UK is highly dependent on its IT workforce. Information Technology is the foundation of business and consumer services, health, leisure and social networking. Information Technology is expected to continue to remain of the 'highest order of economic significance' [1] as 'across all industries it is the combination of highly skilled IT & Telecoms professionals, technology aware business leaders and competent IT users that enable an organisation's effective participation in the UK and global digital economies'. [2] The UK's global position with regard to IT investment and use remains high, but over recent years the UK's global ranking has declined, and is now consistently below that of other leading nations. At the same time, 'businesses in emerging markets are investing aggressively in ICT'. [3] The Digital Industries are at the heart of the Information Economy. The Information Economy Economic Estimates report published in October 2013 [4], provides economic and employment estimates for the UK Information Economy as defined by The Department for Business, Innovation and Skills (BIS).

Key Data from the report includes:

- In total, GVA from the Information Economy is estimated to be approximately £72bn representing 5% of the UK total and at £99,000 per head, GVA per worker in the Information Economy is more than double the industry average (£47,000).
- The number of people working in the Information Economy industries grew 8% over the 2009-12 period - a rate four times that recorded for the UK workforce as a whole (2%).
- Between 2009 and 2012 the number of Information Economy enterprises rose by 7% even as the overall number of enterprises in the UK declined by 0.1%.
- The Information Economy now comprises 131,000 enterprises and 138,000 local units representing 6% and 7% respectively of the total number in the UK.
- With a workforce of 760,000 people, Information Economy firms accounted for approximately 3% of the entire UK workforce though the figure rises to 1.4m or 5% when taking into consideration the Information Economy specialists employed in other sectors.

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Against this backdrop, research by the UK Sector Skills Council for IT and Telecommunications [2] have reported that:

- 129,000 new entrants are required each year to fill IT professional job roles in the UK but 50% of graduates are recruited from non-Computing disciplines while many Graduate jobs are left unfilled.
- 82% of the IT workforce is male.
- Applications to Computing Degrees declined by 28% between 2002 and 2010 whereas the number of applications to all HE courses increased by 51% over the same period.
- Unemployment for Computing graduates (14%) is the highest of all subjects (9% across all graduates in 2011)
- Clearing now accounts for 21% of the total acceptance into Computing degrees and HNDs (UK domicile); (14% all subjects)
- Over a third of Computing graduates said they would change subject if they were choosing to take their course again; the second highest subject 'dissatisfaction'.

The same report concluded that digital skills are now essential right across the workforce in all sectors and that to sustain the UK economy, businesses in all sectors need to rapidly move up the maturity curve in exploitation of technology. All business managers and leaders need a strategic understanding of how to apply technology for business benefit. But the smaller the company and the older its leaders, they less likely they are to embrace technology. Virtually all positions being recruited for across the job market demand IT user skills. Today, 36% of development need for IT user skills is at 'advanced' level or higher (level 3 plus). The UK education system continues to fail to prepare young people for the digital economy and recognising this, the UK Department of Business Innovation and Skills has funded a number of initiatives, including the sponsorship of a new type of degree programme, the purpose of which is to create a radical improvement in the linkage between employer needs and university curricula, in order to increase the volume, calibre and effectiveness of graduates entering IT-related careers.

2. A New Type of Industry Driven Degree Programme

In 2005, e-skills UK brought together a consortium of employers and universities to create the new Information Technology Management for Business (ITMB) degree framework, structured to meet student, university and employer needs in the rapidly changing IT environment. IBM, Computer Associates, BT, Norwich Union, Microsoft, HP, Morgan Stanley, Ford and Fujitsu collaborated to define learning outcomes for the ITMB framework against which four universities created new degree courses. The framework gave equal weighting to four elements of learning; business, technology, personal skills and project work. Employers agreed to be actively engaged in both development and delivery, including providing 'business guru' lectures, project work and student placements.

The primary benefits expected from the new programme included:

- Enrichment of the learning experience for students through close partnership with employers, including the integration of learning with work-based projects and work experience;
- Improvements in student employability and the gender balance on IT-related courses;
- Development of deeper relationships between HE and industry;
- A high profile demonstration of how commitment from employers and universities can be leveraged and scaled to make a substantive contribution across the Higher Education sector;
- A degree programme that would set new standards in terms of:
    - Effective employer engagement;
    - Attracting the highest quality students;
    - Appeal to women as well as men;
    - Degree completion rates;
    - Progression into IT careers.

Roles and responsibilities were established and allocated to the participants.

e-skills UK were to:

- Be responsible for programme management, including:
    - Ensuring the overall success of the programme
    - Delivering against milestones on time, in budget, to the highest quality
    - Communications
- Ensure courses are launched:
    - Securing university commitments
    - Supporting new course development
    - Mapping and validating courses against the ITMB framework
- Support student recruitment:
    - Undertaking national marketing campaign for students
    - Supporting universities' student recruitment activities
- Support course delivery:
    - Attracting and retaining employer commitments
    - Orchestrating employer guru lectures
    - Creating a model for integrated student placements
    - Quality assuring course delivery in terms of meeting employer requirements as set out in the ITMB framework
- Ensure ongoing success of the degree:
    - Maintaining the currency of the ITMB framework in terms of meeting employer requirements
    - Ensuring sustainability

Employers were to:

- Support new course development
    - Sharing graduate development approaches and materials
    - Helping universities to create degrees based on the framework
- Support student recruitment
    - National campaigns
    - Individual university recruitment activities
- Support course delivery:
    - Deliver employer guru lectures
    - Provide student placements
- Help ensure ongoing success:
    - Contribute to ongoing development of the framework through the Employers' Curriculum Forum collaboration

Universities were to:

- Develop new courses which meet ITMB criteria
- Prepare for offering the degree, including:
    - Undertaking staff development and / or recruitment (as required)
    - Ensuring the appropriate infrastructure is available
    - Developing relationships with employers
- Undertake local marketing for students
- Deliver high quality courses, including, with e-skills UK's support:
    - Making available guru lectures
    - Arranging suitable work placements
- Contribute to ongoing development of the framework

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The innovative structure of ITMB was designed to link cutting-edge technology to innovative business practices and provide a deep insight into management issues faced by technology-intensive organisations. Graduates were developed so as to embark on their careers with a balanced set of highly sought after IT professional and leadership skills.

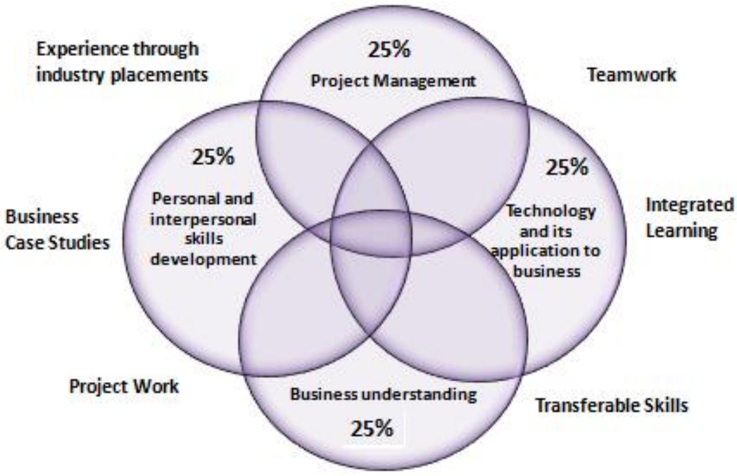

Figure 1. The Four Key Components of the ITMB programme

Universities wishing to run the programme were (and are) required to seek and obtain endorsement as a ‘Tech Gold’ Degree by the e-skills employers group (now referred to as the Tech Partnership). The endorsement process which considers content, learning outcomes and skills requirements, delivery method, assessment and admissions, is designed to be thorough enough to ensure the compliance of the University’s new course with the ITMB programme, its criteria and core content

The employer specified, employer endorsed ITMB programme was rolled out in the academic year 2005-06 and has since grown as follows:

Started 2005-06	Started 2006-07	Started 2007-08	Started 2010-11	Started 2011-12	Started 2012-13	Started 2013-14
*University of Central England (UCE)	*Keele University	University College London	Aston University	Glamorgan University	Glasgow Caledonean University	University of Chichester
University of Greenwich	Oxford Brookes University	University of Exeter		University of Hertfordshire	Queen Mary University of London	University of Derby
Northumbria University	University of the West of England (UWE)	Lancaster University				University of West London
*University of Reading		Loughborough University				
		University of Manchester				
		University of Sheffield				

Table 1. ITMB University Partner Start Dates

*No longer offering the ITMB degree

Since roll out the programme has grown slowly but steadily with around 100 (mainly Blue-Chip) UK employers now supporting the programme across 18 UK universities.

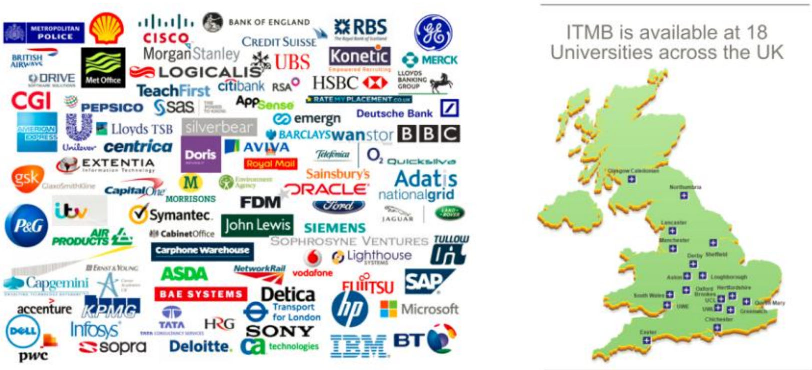

Figure 2. The ITMB Business and Academic Partners

The support of such a large number of Tech Partnership companies has proved both valuable to and popular with students. Employer involvement has taken a number of forms including:

- delivering GURU lectures
- participation in Graduate Development sessions
- the sponsoring of both inter and intra student competitions
- the hosting of ‘all student away day events’
- mock selection centres/interviews

Employer ‘know-how’ is very much key to the undergraduates’ experience throughout the ITMB course and the e-skills invited ‘Guru Lecture’ series is a key element in bridging the academic and business worlds. There are approximately 12 Guru Lectures throughout the academic year and undergraduates on the ITMB Degree course are strongly encouraged to attend all of them. Lectures are hosted (in turn) by one of the participating universities and broadcast live to the others using web conferencing software. They are intended to inspire and motivate the students and to support their studies by showing the importance of theory to the world of practice. Speakers and topics are arranged in negotiation with the participating universities and span technology, business, project management and personal/interpersonal skills.

In accordance with the programme’s focus on employability, representatives from members of the e-skills UK employer community (including e.g. BT, HP, IBM and the Environment Agency) have run a series of workshops here at UWE at which they told students about their approach to graduate training and career development and about placement opportunities and internships. Recent graduates frequently attend (and often lead) these sessions in order to provide students with an insight into the nature of their employer’s graduate development scheme and to tell students what their day-to-day working life is like. These sessions are geared primarily to second year students; however, final year students are also welcome to attend if they are able to do so.

Twice each year, ITMB students have the opportunity to practice their skills in front of executives from the ITMB partner companies at ITMB regional ‘All Student Events’. At these events students from the various universities offering the award take part in a variety of inter-university first-year competitions, get help and advice from representatives of up to 50 different employers and listen to a number of keynote speakers. An important part of the event is an inter-university competition in which student teams present and defend their views on an employer defined ‘business challenge’. UWE’s first year inter-university competition entries are developed in Peer Assisted Learning (PAL) sessions, under the guidance of the second-year PAL tutors. Participation in these competitions helps students to develop personal and

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interpersonal and project management core skills as well as enhancing their knowledge and understanding of emerging areas of importance. It also helps to instil a strong sense of self-worth in both the participating students and the wider cohort, and helps students to understand that academic achievement is only one part of the skills mix required for success in life. PAL leaders benefit greatly from their role as facilitators of competition preparation and post-event critical reflection, especially in relation to the development of the skills and qualities of leadership and professionalism. Sana Shar (a recent UWE ITMB graduate) summed up the importance of events like this when she said: *"It makes us feel very special to know that senior people in large organizations are willing to help us to develop our potential. I feel incredibly lucky to have been given this opportunity and I am going to work as hard as I can to take full advantage of it"*. Student Events have been held at the BT Tower in London, CA's Ditton Manor conference centre in Datchet, near Slough and Procter and Gamble's UK headquarters in Weybridge.

Second year BSc ITMB students are expected to attend one or more 'Mock Interview' days held at the head office of one of the ITMB partner companies. These days are run just as a professional interview/selection day would be, with the additional benefit of feedback and advice from members of the e-skills UK Employer's Forum. Last year, students were interviewed by representatives from: Accenture, Procter & Gamble Cisco, IBM, Logica, Morgan Stanley, ITV, the Metropolitan Police and Symantec.

3. Some Impressive Results to date

Student performance on the ITMB programme at UWE has been excellent, making it one of the premiere awards offered by the Department of Computer Science and Creative Technologies. Students on the programme get better marks, a better degree classification and are more likely to get professional employment than students on other awards.

MODULE CREDIT LEVEL 3

		11/12			12/13			13/14		
		Enrols Count	Module Mark	Pass Rate %	Enrols Count	Module Mark	Pass Rate %	Enrols Count	Module Mark	Pass Rate %
UWE AVERAGE		121,298	54.1	86.3%	115,299	54.4	86.2%	97,581	56.2	85.3%
Department:	Computer Science and Creative Technologies	8,026	55.0	79.8%	6,612	55.3	80.8%	5,993	57.2	81.3%
Programme:	BSC (HONS) INFORMATION TECHNOLOGY MANAGE	143	66.3	98.6%	171	60.3	92.4%	243	61.9	92.2%

Table 2. Module Marks and Pass Rates: Programme: Department: University (11/12-13/14)

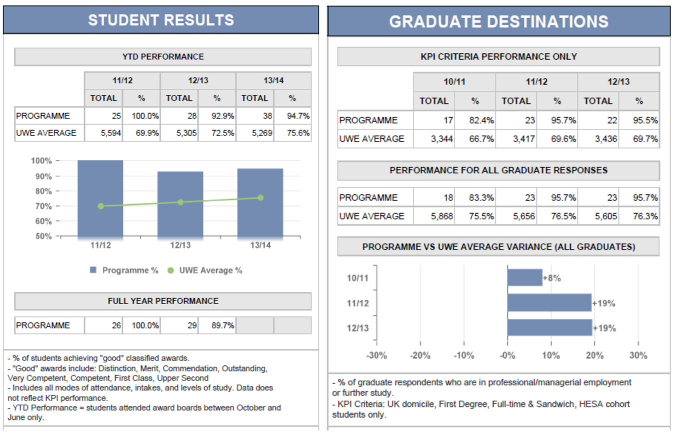

Fig 3. Student Results and Graduate Destinations (11/12-13/14)

The University of the West of England, Bristol (UWE) is one of the longest standing e-skills UK HE academic partners, with recruitment to the ITMB degree programme commencing in 2006/07.

The ITMB Partnership is the glue that binds academe, business and government together and the employer partners play a key role in both the development and the delivery of The ITMB programme. The high level of employer involvement helps to confirm and consolidate the relevance and importance of the topics and subjects covered by the award, to broaden the context of study for the students through exposure to contemporary applications, initiatives and issues and to inspire them to see their education as a powerful force in their personal and professional development.

Student performance and the student experience on the ITMB benefits enormously from the unique partnership that is brokered by e-skills UK. This is clearly evident from the key performance indicators collected by the university, from the National Student Survey and from graduate employment statistics. UWE is very proud of the performance, achievements and attitude of its ITMB students and recognises the pivotal role of the ITMB Partnership in helping to establish and run programmes within which students are inspired, encouraged and enabled.

4. Introduction to the new SDfB degree with a focus on Software Engineering

Through the ITMB degree, The Tech Gold programme has developed a strong track record of attracting, retaining and producing excellent work-ready graduates. Stage 2 in the roll-out of the programme involves a more technical degree programme (the BSc (Hons) Software Development for Business; SDfB) which is aimed at producing high quality, work ready software developers, with core competency in Software Engineering..

The SDfB degree is aimed at high potential, mathematical, creative thinking students who are interested in the design and development of software applications and systems. Alongside building technical aspects of complex software systems, the taught programme will cover the team-working, personal/interpersonal, management and project skills required by all the key roles that drive and exploit fundamental technologies.

As with the ITMB, the Software Development for Business degree has been developed in collaboration with some of the UK's leading companies and Universities. The programme commenced in September 2014 and having successfully achieved Tech Gold endorsement, UWE is scheduled to start running the course in 2015.

The overall aim of this new programme is produce software development graduates who are capable of making a real contribution to their new employer within a few months of graduation. The programme will strive to improve software development practices through a curriculum that connects current research, education and practical development, covering all fundamental principles of software engineering.

As with the ITMB, the programme will deliver a team-based, project-centred curriculum encouraging relevant work experience to build sufficient technical, business and management knowledge. Students will be able to develop high quality, well-designed software within a global and changing context, through sound academic knowledge and practical abilities. The four key themes are the same as for the ITMB programme, but (unsurprisingly) the proportions and some of the detailed content are different. Whereas the ITMB is intended to produce a new generation of Business Analysts and Project Managers, The SDfB programme is intended to produce Systems Developers and Software Engineers. The balance, therefore, is weighted more heavily towards Technology, with 60-65% of the programme covering Technology and, in particular, Software and the other themes each representing around 10-15% of the curriculum and student effort.

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Figure 4. The Four Key Components of the SDfB programme

As with the ITMB, The Tech Partnership employers are responsible for setting the overall strategy for the SDfB programme and are committed to maintaining its quality and its relevance to their respective industries. Again, as with the ITMB, they will play a key role in the delivery of the programme, by providing hands-on support to SDfB lecturers and students. In this way it will help students to develop the knowledge and the skills required to enable them to secure careers in the Information Economy - particularly within its own member companies. The high level of employer involvement will help to confirm and consolidate the relevance and importance of the topics and subjects covered by the award, to broaden the context of study for the students through exposure to contemporary applications, initiatives and issues and to inspire them to see their education as a powerful force in their personal and professional development.

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Professional Skills Needed by Graduates Entering the Consulting Engineering Field

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Abstract

The senior author completed a non-traditional sabbatical spent with a highly successful, thirty-seven year old, medium-size environmental consulting firm. The authors reflect upon the skills needed by engineering graduates who enter that industry and the complementary roles of engineering education and the firms themselves in seeking to develop those skills. PEER Consultants, P.C., is headquartered in Washington, DC with offices in Baltimore, MD; Burlington, MA; Clearwater, FL; and Laurel, MD. PEER, with over 100 employees, primarily works with municipalities and has performed work in a number of environmental areas. In addition, a number of PEER engineers are "embedded" in client facilities rather than a specific PEER office, complicating efforts at communications. The following discussions integrate what happens (or does not happen) in engineering curricula and what PEER is doing to continuously maintain its competitive advantage.

Keywords: *Consulting, Engineering, Curriculum.*

1. Introduction

The senior author completed a non-traditional sabbatical spent with a highly successful, thirty-seven year old, medium-size environmental consulting firm. The authors reflect upon the skills needed by engineering graduates who enter that industry and the complementary roles of engineering education and the firms.

PEER Consultants, P.C., (PEER) is headquartered in Washington, DC with offices in Baltimore, MD; Burlington, MA; Clearwater, FL; and Laurel, MD. PEER, with over 100 employees, primarily works with municipalities and has performed work in a number of environmental areas. In addition, a number of PEER engineers are "embedded" in client facilities rather than a specific PEER office, complicating efforts at communications.

PEER has an unusual and strong commitment to its core values. This is in part due to the fact that the Founder, Dr. Abron, has been at the helm for all thirty-seven years of PEER's existence and remains the CEO. This has provided a constancy of purpose that helps keep its focus on people, both within and outside the organization. This is further exemplified by two foundations, PEER Africa and PEER Global, formed and nurtured by Dr. Abron. PEER and PEER Africa won an award from the American Academy of Environmental Engineers. They were honored with the "*2012 Superior Achievement Award*" in the Environmental Sustainability category for the Witsand iEEECO™ Sustainable Human Settlement Project in Cape Town, South Africa.

2. Observations

During his seven-month stay with PEER, the senior author made observations of activities within the firm and attempted to mentally connect them with his academic experience. Conversations with the second author and others in the firm helped confirm areas of interest and/or concern, as explained in the following paragraphs.

Communications (individual) both verbal and written – This concern has existed for decades, but its dimensions have changed, in part due to technology. Writing must include numerous types, ranging from short, interoffice updates to full technical reports. Verbal communications can include a brief summary to clients and/or conference presentations. Journal articles and blogs reach a different audience. One fundamental part of the communication process that is often forgotten is *listening*.

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Integration of technology must enhance communications while avoiding technology overkill. Means of developing these skills should begin with the university, including communications in a diverse organization. Diversity in this sense refers to technical background, gender, ethnic background, learning/personality type, and, of course, this is amplified by physical separation.

There is a difference between formal and informal communication, even on technical issues. In some instances, these occur in very natural ways. Colleagues may bump into each other in the hallway, the elevator, and their offices and have a dialogue about an ongoing problem or concerns. The use of e-mail generally is an informal communication method, although some messages require a formal tone. The informal communications may use shortcuts in the language or nicknames and the like, where this would not be appropriate in a formal document. There are reasons for having conversations as opposed to presentations or vice versa, as presented very nicely in a recent article. [1]

Communications across the company / Knowledge management – Understanding how to establish communications with others in the company is critical. It is important to know where information and experience resides within the company to enable learning from previous experience and developing collaborations. This effort is known as knowledge management [2]. Technology can help in this effort, but the ultimate objective is to bring people together and to increase sharing of knowledge.

Project management – Successful (exceeding expectations), timely, project completion within budget is essential to a consulting firm's success. Students should be exposed to project management processes with their curricula, e.g., during and before senior design. However, actually managing projects in a complex, schedule-driven company is more difficult than they would ordinarily face in a university. PEER recognizes that project management is not simply a promotion based on years of experience, but must be based on sound preparation. Not everyone will become a project manager.

Client relations- Client relations are central to consulting firm success. While there may be corporate client relation tracking, each engineer must understand the seriousness of their interactions with clients. Guidelines are currently being developed for this role. The various forms of communications cited earlier are all involved in client relations. For example, PEER has a longstanding policy of including a key person from the client as the senior author on conference presentations. Listening can be very important. Not only does it help know if the client is happy with the work, but it may also alert the employee to possible additional future work.

These key elements of success must be achieved in concert with a number of other factors, including team skills, innovation, understanding company profitability and individual billability, helping create new company directions, special problems and opportunities arising from being embedded, and continued learning in a world of information overload. Discussions of integration of these elements within PEER and universities will denote successes.

This continuum of engineer growth begins in the engineering curriculum and persists during his or her career. While ultimate responsibility for this continuous learning lies on the engineer, understanding approaches to lifelong learning begins in the engineering curriculum. It can be facilitated and incentivized by the consulting firm as well.

3. Survey of PEER Employees

In order to better understand issues about observed behaviors, the authors conducted a survey of PEER employees. Employees were asked to assess areas in which they would have benefited from additional education. By implication, these would indicate areas where they felt most need in either the work in which they had been involved or their perception of likely future success. They were asked to make their assessment on a five-point Likert scale including "Strongly Disagree," "Disagree," "Neutral," "Agree,", and "Strongly Agree.". The topics listed were the following: Team skills, Communication skills –writing, Communications skills – presentations, Communications with colleagues, Project management, Client relations, Leadership/management, Systems perspective, Understanding and appreciation of the diversity of colleagues, Appreciation of different cultures and business practices and understand the practice of engineering is now global, Multi-disciplinary perspective, Understanding of the societal impacts of engineering decisions, Understanding of economic impacts of engineering decisions, Understanding of environmental impacts of engineering decisions, Sustainability, Ethics, Innovation, and Lifelong learning. Instructions to the survey respondents were as follows: For each of the following items, please indicate how strongly you wish you had received more education in that topic. If you say "Strongly Agree," that is the equivalent of saying "I strongly agree that I should have had more education in the topic…"

It should be noted that not all respondents were engineers by background. However, it was deemed important to reach out to them. PEER is an engineering firm, and these people work in teams that include engineers and do engineering work. It is believed that their responses would be meaningful. Indeed, when results were segmented by background and by the project areas in which they operated, similar trends and topic rankings were observed. A total of thirty-five responses (over sixty-two percent of those given the survey) were received from across the company's disciplines, providing a representative sample.

The topics selected were, in large part, taken from the 1994 report [3] that paved the way for the current ABET outcomes-based assessment. A few were added to reflect the specific culture, core values, and directions of PEER. PEER has always wanted to make a difference, and it has hired in such a way as to develop a diverse workforce to provide a wider range of opinions and to assure that societal impacts are considered in developing solutions.

To simplify review of the results, a weighted number was calculated for each topic by assigning a value ranging from 1 for each response of "Strongly Disagree" to 5 for each response of "Strongly Agree.". When results were sorted in this manner, the topics presented in terms of perceived need are presented in Table 1.

Table 1. Results of Survey of PEER Employees

Topic	Weighted Response
Team skills	2.94
Communication skills -writing	3.41
Communications skills - presentations	3.26
Communications with colleagues	3.06
Project management	4.18
Client relations	3.70
Leadership/management	3.85
Systems perspective	3.43
Understanding and appreciation of the diversity of colleagues	2.94
Appreciation of different cultures and business practices, and understand the practice of engineering is now global	3.26
Multi-disciplinary perspective	3.30
Understanding of the societal impacts of engineering decisions	3.58
Understanding of economic impacts of engineering decisions	3.53
Understanding of environmental impacts of engineering decisions	3.58
Sustainability	3.52
Ethics	3.15
Innovation	3.67
Lifelong learning	3.48

The results of the survey supported the author's observations in many instances, although there were a few differences. Having noted these areas of concern, efforts must be directed toward improvement. There will be two points here, with one being what engineering educators can do within the curriculum to prepare students. The other will be what PEER has been doing to try to overcome these issues. Perhaps looking at the combinations of these efforts in the following sections will reveal best approaches.

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Notice that the highest rated topics – Project management and Leadership/management – both seem to relate to project management skills. The topic of team skills does as well. It is interesting that team skills scores at the very bottom of the list. This should be an integral part of effectively managing projects. It is felt that scores likely are low because most university programs do not emphasize team skills, leading to a failure to recognize the importance of these attributes. This will be discussed in more detail for directions that might be indicated from these findings for engineering education programs.

There are a few other things worth a brief reference. The items on societal impact, economic impact, and environmental impact are taken directly from the ASEE report [3]. Sustainability, now recognized as the confluence of those three impacts, was added. Interestingly, interest in increased learning in all four of those items is essentially identical. In some cases, it is believed that lesser weighted responses may reflect one of several factors: a belief that no further skills are needed, a feeling the particular attribute is not important in their job, or even possibly a misunderstanding of the attribute itself due to the employee's background. PEER will use these results as the starting point for a dialogue concerning all of these items to ascertain how they can not only be understood but further developed within each employee and within teams.

To acquire a complementary view, several senior leaders in PEER were asked to indicate their perception of how well the younger engineers performed in these areas. Further, they were asked to indicate the importance of each. Their observations reinforced areas of concern. They also indicated that these very areas were of most importance to the company.

4. PEER Actions

PEER has been continuously moving to improve itself in all areas. Many of the things that are cited in the following statements about PEER's actions predated any of the survey findings. Of course, this information may also be helpful and reinforce their efforts.

A team has been formed to discuss project management. PEER has also secured ten virtual seats in an on-line course on project management. The team is acting to not only enhance project management skills, but also to provide a sounding board for those managing projects who encounter issues outside their experience. Further, the team will provide useful materials and suggestions for future project managers in the company. Some are certified through the Project Management Institute [4].

PEER has for years held a company-wide teleconference on Friday mornings. This enhances knowledge of what others in PEER are doing. It also provides people an opportunity to hone their presentation skills.

PEER has invested in comprehensive software package to provide a basis for knowledge management within the organization and to strengthen project and business management. PEER has always archived its reports, proposals, and the like, and these are available online. However, there is a current effort to strengthen the holdings and search capabilities to better enable finding the pertinent materials. This will include linking names so that people in the various offices can easily identify those with relevant experience to their problems when seeking help. Of potentially even greater value is the work to translate all budget, personnel involved (billed or otherwise), and milestones to provide so-called waterfall graphs and succinct snapshots of progress and projections. The same type of data for the operations of PEER in total are being developed to simplify and enhance regular leadership management meetings to monitor the health of the company and make decisions on directions. These efforts are providing not only better and quicker actions, but also enabling PEER's leadership team to spend more time on strategic initiatives.

PEER currently spends a lot of time by senior personnel overseeing both written and oral communications as well as presentations. During the senior author's time in Washington, young people who were preparing abstracts for conferences and the resulting presentations were steered to the senior author for guidance. He tried to work with them to not only produce a good product but also so that they might learn from the process. All of this represents a significant time commitment to the firm with a resultant cost. Of course it was very cost-effective to use the senior author in this regard, but PEER is looking at a variety of options to enable people to become proficient in communications. This would free up the time of the senior people in the firm to tackle many other important tasks necessary for success.

5. Implications for Engineering Education

Many, if not all, of the attributes under consideration appear within senior capstone design courses. These courses may be one or two semesters, but they have a number of expectations. The senior author has significant experience in those courses and in that what other institutions report about their practices. In addition, the attributes cannot be developed solely in that senior project. They have to be embedded throughout the curriculum so that students have the necessary capabilities and can demonstrate those in the final project. Given that, many of the skills to be developed would have to be incorporated into the curriculum beginning in the freshman year.

The senior design course, or capstone course, is required by the engineering accreditation body, or ABET. As they state, students must be prepared for engineering practice through a curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints [5]. Thus, this is a requirement for engineering programs. The exact approach may vary from program to program. Examples can be seen at many universities. [6] – [9].

Each program must develop key student outcomes, as well as program educational outcomes. The mechanical engineering program at the University of Texas at El Paso (UTEP) has three program educational objectives. One is especially pertinent to the discussions herein, specifically "Our graduates excel as engineers with solid technical skills, strength in design, and an ability to work with complex engineering systems." It starts students down the road to life-long learning by requiring them to undertake activities outside the traditional classroom [10].

The ability to communicate effectively has been an ongoing issue with graduates of universities in all areas, not just engineering, for a long time. This of course leads to people having difficulty when entering an organization where communications are critical. To better study ways in which to improve, the questions were deliberately broken into different communications areas.

Writing is used in a number of settings which may include coursework such as technical writing. However, that is insufficient for the level of skills needed for the different types of publications that graduate must prepare. This preparation is most effectively achieved by carefully planning different kinds of writing projects or assignments throughout the curriculum.

There are, of course, many lessons to be drawn from this recent experience. Further information can be extracted from surveys and conversations with PEER leadership and engineers. A beginning point would be to think in terms of the topics indicated in Table 1 that were present in the survey. The topics are closely aligned with the expectations from a senior design capstone course. While not all of these need to be included in a particular course, there need to be enough constraints that students can effectively apply what they have learned in earlier years in the curriculum and be certain that they can handle projects they will undertake in the consulting engineering industry. Many of the observations we have made would be applicable to people entering any other industry, but there may be some differences here, and it will be the focus of these conversations.

Referring to the results of the survey, coupled with experience in the firm, it appears that the topics requiring the most attention are project management, communications of all types, and a full understanding of sustainability and its three elements. In addition, there is the underlying expectation that people will know how to work in teams and that they will understand ways to craft an innovative solutions to problems. In some instances you will note that there are other topics that appear to be linked to those indicated. For example, leadership and management seems to have some relevance to project management. However, it is important to note that these will not be attributes that are fully developed simply within the capstone course itself. This is true whether it is a one semester or two semester capstone course. This course must be the culmination of the entire curriculum.

As a result of the experience during the sabbatical, the senior author is undertaking an effort to redesign the entire design experience within the Mechanical Engineering Department at UTEP. The lessons learned at PEER will be invaluable in that process. There are many programs in the US with excellent designs experiences, and UTEP is committed to be in the forefront of that effort. Of more ultimate concern is enabling students to have a sufficient background so that they are successful not only in the capstone course but also in their future work. It

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is believed that this will enhance their ability to find excellent opportunities in whatever industry they choose, including the consulting engineering industry.

Project management is obviously a key to efforts in the consulting engineering industry to assure that the firm not only will be extremely successful but they will enable the company to be profitable. In PEER's case, this must be done in concert with the core values described herein that indicates that society must benefit from engineering solutions. This means there is a direct tie to sustainability. There are a wide variety of approaches to teaching project management within engineering curricula and within the capstone course itself. Some programs appear to have an extensive overview of project management while others do not provide much guidance to students throughout the curriculum. Smith [11] has prepared an excellent book to coordinate expectations for teamwork and for project management. While this can certainly provide a framework for the capstone course, the author contends that elements of it need to be built in to the earlier parts of the curriculum, with some materials being presented and/or reinforced within every semester. Elements for inclusion should include, at a minimum, the following: requirements, task definition, scheduling, costs and resources, and communicating progress and results.

There is a significant amount of literature on teams and their behavior. For this particular conversation, it is pertinent to reference a few of the works that enable teams to come closer to realizing their full potential in terms of innovation. These include elements such as design thinking [12], liberating structures [13], and ideation [14]. In recent years there has been an extreme growth of the concept of Idea Fests (or Idea Festival or Ideas Festival) to advance innovative thinking and collaboration [15]. At the highest level, this can represent efforts by companies and large organizations to find approaches, processes, and new markets that may be useful in the future. Today, an increasing number of universities are holding their own Idea Fests. This concept is being considered within the Mechanical Engineering Department as a way of not only elevating interest in design but celebrating student work. This concept may also serve PEER well in the future.

Diversity in many forms is extremely helpful if you want teams to develop innovative solutions [16]. One of the worst things one can do is to create a team of people whose thought processes and experiences, as well as their personality types, are all essentially the same. Diversity can have many characteristics. Certainly, one looks for people with different experiences, different personality types, different cultural backgrounds, different genders, and different levels of experience. Different levels of experience often correlate to different age groups and therefore different generations. All this argues for real care in the way teams are selected to study some issue within a program or to create a design. The practice of having teams self-select to include friends can have several problems. This methodology does not assure the diversity of thoughts and experiences that one would like to see. Further, since team designs often require peer evaluations, good friends may be more reluctant to be as forthright in ratings and comments. PEER's make up provides real opportunities to benefit from diversity within its employees and teams.

A study was reported recently [17] in which the maturation of teams was considered as a basic variable. Researchers reviewed Broadway plays from the last 70 years or so. They observed the success of the plays measured against the level of previous experience within the team that created the play. A numerical indicator of that experience ranged from 5.0 for teams that have worked together many times to 1.0 for a team where all the team members were working together for the first time. The highest success rate corresponded to a team evaluation of about 2.7. This finding is probably not surprising, as it indicated that teams need some time together to understand each other and to be able to do develop not only the feeling of camaraderie but trust that is necessary to be innovative. At the other extreme, those teams with five as an evaluation most likely have begun to limit the number of directions they would take and to reuse approaches that are most comfortable for them. These types of studies need to be performed for broader ranges of projects and observations made. However, it certainly indicates that the team makeup is critical in being innovative. This, of course, only talks about their experiences with each other and does not include increased value due to a variety of forms of diversity.

6. Conclusion

Conversations with leaders in other consulting firms of all sizes indicates that these are common problems. Therefore engineering education must assert itself with respect to the skills it provides, but for some period of time consulting firms cells may continually have to help people make the transition. Of course, this can be very costly for the companies in terms of time that might be spent elsewhere. Therefore, universities must not only be aware of needs within the consulting engineering industry, but partnerships between universities and firms may help both parties keep current.

This experience was superb for both parties, and it is recommended that more academic faculty seek similar opportunities. It must be emphasized that a key to success is the commitment of the consulting firm to the endeavour. PEER and its people created an environment and support that made this a truly exciting and beneficial experience.

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Student motivation in the development of professional skills

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Abstract

Within the packed undergraduate engineering curriculum the development of students' professional or 'soft' skills is often hampered by the demands of the numerically and technically demanding content. However, engineering employers are increasingly seeking graduates who have the right employability skills and so can make an immediate effective contribution in the workplace. The challenge for programme developers within Higher Education is to maintain the technical excellence within engineering degrees whilst simultaneously developing those soft skills and business awareness that industry has identified as being so important when recruiting graduate engineers. This is especially the case for Ulster University, which as a regional university, sees the majority of its graduates finding employment in small or medium-sized enterprises. Although educators generally have moved to meet both this expectation from employers and also to satisfy requirement of professional bodies for accreditation, many students still undervalue the opportunities they are offered to develop their professional skills. This paper presents the findings of a study conducted among undergraduate engineering students at Ulster University to elicit their attitude to the development of their professional skills. It compares the alignment of student attitudes with employer expectations. The impact of different approaches to the development of 'soft' skills is reported. Finally, approaches to curriculum design and strategies that may be adopted by course designers to help motivate the development of professional skills are described.

Keywords: *engineering education, curriculum design, professional skills.*

1. Introduction

The Higher Education environment in the UK has been transformed with the advent of tuition fees [1]. Since student loans to cover tuition fees were first introduced in the UK in 1998, there has been a gradual increase in emphasis on the transferable and employability skills acquired by the student during their undergraduate studies. As university graduates are required to repay their student loans when they reach a government-set income threshold, most graduates aspire to obtain a job quickly after graduation and commence loan repayment.

Universities and colleges are finding themselves and their courses the subject of unprecedented levels of debate around value for money and cost benefit analysis. Potential students are increasingly becoming discerning 'customers' and are quite rightly encouraged to weigh up carefully the cost of a university education compared to other routes into worthwhile careers. This is particularly important in engineering education, where the UK government is promoting engineering higher apprenticeships and foundation level degrees, inter alia, as more cost effective routes to entry level careers in the engineering industry.

At all levels of tertiary qualifications, curriculum developers in engineering education are increasingly aware of the importance of providing opportunities for students to develop and hone the 'softer' professional skills that are recognised as increasing their attractiveness to potential employers [2,3]. Curriculum developers are faced with expectations and pressures coming from employers, subject benchmark standards, professional bodies and students, as illustrated in Figure 1. This paper explores the issue of professional skills development from the perspective of the key stakeholders and presents the approach adopted in curriculum design in the School of Engineering at Ulster University.

2. Considerations in curriculum design

2.1. Expectation from Employers

Communication skills, team-working skills, integrity, intellectual ability and self-confidence are ranked by 80% of graduate recruiters as the five most important generic skills and capabilities sought by employers generally [4]. As engineering educators, we recognize that our graduates require all these generic skills together with those attributes and skills that have been identified as being important by engineering industry. The majority of engineering degrees provide a highly regarded broad based technical qualification that provides their graduates with, inter alia, the mathematical and scientific underpinning relevant in each particular engineering discipline, leadership and managerial skills, an understanding and ability in product and process design, together with an appreciation of the social, ethical and environmental protocols associated with the engineering profession. In a study published by the Royal Academy of Engineering (RAE), engineering employers in the UK identified the six most important attributes when recruiting engineering graduates [5]. These are: application theoretical knowledge to real industrial problems, theoretical understanding, creativity and innovation, team-working, technical breadth and business skills.

Large global engineering multi-national organisations have the resources to recruit graduates and then train them in-house to the required threshold on customised graduate training programmes. Since the vast majority of engineering employers within Northern Ireland are small to medium-sized enterprises (SMEs) that generally lack the necessary resources to deliver company specific development programmes, it follows that engineering courses within a regional university such as the Ulster University must be responsive to employers' needs and embed these important employability skills within their degree programmes so that students are industry-ready on graduation [6].

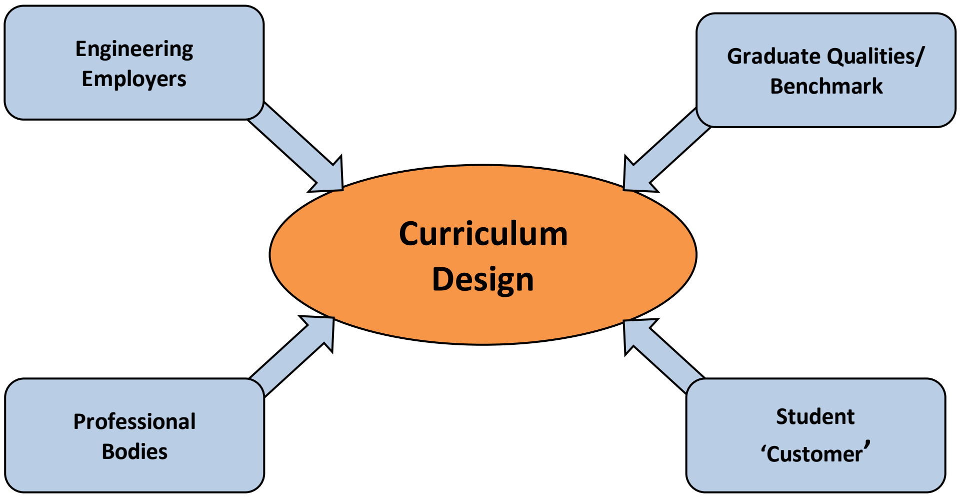

Figure 1. Reference points for curriculum design

2.2. Expectation from University

It is well recognised that encouraging skills development is a key part of the UK Government's strategy for improving the productivity of the UK's workforce [7]. Amongst the reference points that course teams are can use to inform the development of programmes are the subject benchmark statements and university specified graduate qualities.

The Quality Assurance Agency's (QAA) subject benchmark for engineering describes the characteristics of engineering graduates as [8]:

> *"They will be rational and pragmatic, interested in the practical steps necessary for a concept to become reality. They will want to achieve sustainable solutions to problems and have strategies for being creative, innovative and overcoming difficulties by employing their knowledge in a flexible manner. They will be numerate and highly computer literate, and capable of attention to detail. They will be cost and value-conscious, and aware of the social, cultural, environmental,*

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health and safety, and wider professional responsibilities they should display: appreciate the international dimension to engineering, commerce and communication, and when faced with an ethical issue be able to formulate and operate within appropriate codes of conduct. They will be professional in their outlook, capable of team working, effective communicators, and able to exercise responsibility."

Each university tends to develop its own approach and expectations for the qualities of its graduates. The graduate qualities that Ulster graduates demonstrate are:

- subject-specific knowledge and skills informed by current research and professional/vocational practice
- flexibility, creativity and an entrepreneurial approach to the resolution of problems
- self-confidence, global citizenship, appreciation of sustainability matters, ethical leadership, and a commitment to life-wide learning, professionalism and employability
- effective collaborative working, communication skills and the capacity for reflective practice, including the ability to give and receive feedback [9].

The EDGE Award has been specifically designed to enhance the employability of Ulster students by providing official recognition and evidence of co- and extra-curricular activities [10]. Each student is encouraged to register for the award at the commencement of their studies. Students are required to take part in a wide range of activities to enhance their career prospects and also to show future employers that they are committed to developing their personal skills. These include typically, volunteering, careers workshops, student representation activities and so on. Ulster offers a dedicated website to facilitate students to develop their graduate qualities in the following areas: self-confidence, communication skills, collaborative working, employability, professionalism, global citizenship, ethical leadership, life-wide learning, problem-solving and enterprising.

2.3. Expectation from the Professional Bodies

Accrediting professional bodies have requirements regarding the development of professional skills. In the U.S., following a major review of its accreditation requirements, ABET introduced a new set of criteria for all engineering programmes [11]. Amongst these were a set of eleven outcomes that graduates should possess. Shuman et al. [12], categorised these as 'hard' and 'professional' skills, as summarised in Table 1.

Table 1. ABET Criterion of Hard, Professional and Awareness skills *(including 2004 changes)*

'Hard' Skills	'Professional' Skills
• an ability to apply knowledge of mathematics, science, and engineering • an ability to design and conduct experiments, as well as to analyse and interpret data • an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability • an ability to identify, formulate, and solve engineering problems • an ability to use the techniques, skills, and modern engineering tools	*Process Skills* • an ability to function on multi-disciplinary teams • an understanding of professional and ethical responsibility • an ability to communicate effectively *Awareness Skills* • the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context • a recognition of the need for, and an ability to engage in life-long learning, • a knowledge of contemporary issues.

Courses offered by the School of Engineering at Ulster are accredited by UK professional bodies affiliated to the Engineering Council. The Engineering Council specifies the relevant output standards for accredited degrees in

UKSPEC [13]. The principal learning themes are: science and mathematics; engineering analysis; design; economic, legal, social, ethical and environmental context; engineering practice; and additional generic skills such as, problem solving, communication, team working and self-management.

2.4. Expectation from Students

Institutions offering Honours and Masters programmes in engineering disciplines operate in a global marketplace. As such, universities and their courses are scrutinised by prospective home and international students weighing up which degree to study and where to study. For international students in particular, the university's ranking in the various league tables is obviously an important determinant. Another important data set is the National Student Survey (NSS), taken by all graduates in their final years of study from UK universities [14]. This survey specifically asks students a total of 22 questions regarding their views on eight broad aspects of their course of study: teaching, fairness, feedback, support, organisation, resources, personal development and overall satisfaction. The results of the NSS inform the Key Information Set (KIS) which is accessible on the Unistats website. Unistats **-** *'the official website for comparing UK Higher Education course data'* **-** provides information about undergraduate courses including student overall satisfaction score in the NSS, jobs and salaries after study and other key information for prospective students, such as accommodation costs [15]. Prospective students use the website to search for appropriate courses and to compare similar courses at different institutions.

3. Engineering programme design at Ulster

Engineering degrees require the students to be competent in the mathematical and scientific principles that underpin the discipline. The challenge for curriculum designers is how best to embed the broad employability skills within a programme that is already packed with the numerically demanding subject material.

A study was carried out on first and final year students on the Mechanical Engineering and Engineering Management programmes at Ulster. These programmes were selected as they comprise the JACS (Joint Academic Coding of Subjects) Mechanical, Production and Manufacturing Engineering grouping at Ulster. They represent approximately 40% of the student numbers in the School of Engineering. A questionnaire comprising a mix of open and closed questions was administered to first and final year students. The aim of the study was twofold: firstly, to determine students' perceptions of what engineering employers want in their graduates and secondly, to elicit students' attitudes towards the development of their professional of 'soft' skills. Approximately equal numbers of questionnaires were returned by first and final years students and the data was analysed using SPSS.

Students were asked to rate as very important, important, somewhat important or not important, the capabilities and skills required from graduate engineers. Their responses were matched against the categories identified in the RAE study as illustrated in Figure 2.

The results show good alignment between what employers want and what first year students think they want. This was an encouraging finding and provided reassurance that a revised compulsory year 1 module, Professional Studies, was indeed delivering its intended outcomes. This module utilises guest lecturers from industry, research institutes, and government agencies. Issues such as CV preparation, presentation skills, interview techniques, real-life design projects, marketing dilemmas are addressed within the context of the engineer as a professional. The module culminates in an industry-sponsored design-build-test-compete project with a prize for the winning team. Students' skills in project management, negotiation, costs control, CAD, team work, collaborative work and oral presentation are all developed in the module. Students really enjoy the competition and rise to the challenge on competition day but it is our experience, that students do not consider this module 'as important' to them as the other more technical subjects on their curriculum. However, Figure 2 shows that students are benefitting from the module in that they have achieved an excellent appreciation of what employers are looking for in graduates.

All students at Ulster on the mechanical engineering and engineering management programmes are required to undertake a year's paid work experience as a student engineer in industry. This constitutes year 3 of their programme and the student is effectively working as a junior engineer. Following successful completion of their placement year, students return to university to complete their degree. Analysis of the questionnaire results revealed good alignment between engineering employer needs and the students' perceptions of those needs. However, the final year students believed 'team working' to be more important to employers than it is in reality,

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and that 'theoretical understanding' as being of less importance to employers than it is actually is. Further research is required to understand why this is the case.

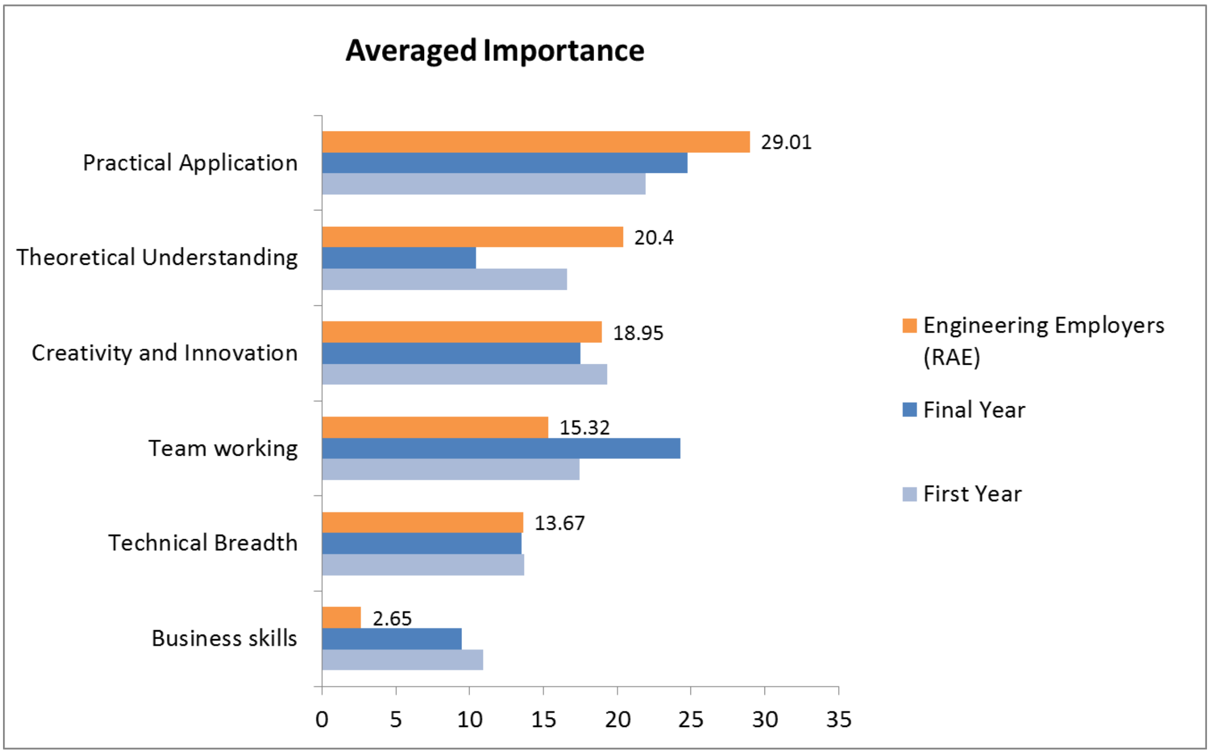

Figure 2. Key skills and capabilities for engineering graduates

Both first and final year students placed a greater emphasis on business skills than engineering employers do, according to the RAE study. Industry in Northern Ireland is characterized by a very high percentage of small to medium-sized businesses and as Ulster's graduates are primarily employed in Northern Ireland, our graduates need to have well-developed business skills and commercial awareness so that they can contribute relatively quickly to business success [16]. Consequently business skills are emphasized in our engineering curricula. The importance of key generic graduate employability skills as identified by Archer et al. [4] was also understood by students. Responses indicated that all students recognized the high value placed by employers on team-working, communication skills, self-management and integrity, and that final year students in particular are more aware of these graduate attributes.

The free response questions on the questionnaire asked students to suggest what course teams could do to further improve students' employment prospects. Employability rates for students from these courses are already excellent with 95% of graduates being employed in a graduate or managerial role within six months of graduation [15]. Table 2 summarises the responses into five broad categories: industry-related, practical skills, communication skills, career planning and course-related.

The priorities for first year students focused on those activities that students believed developed their technical and practical skills. Final year students felt that their professional skills would be enhanced with more career planning for industry-academic interaction.

Ulster University has a dedicated Career Development Centre and provides specific timetabled sessions for students throughout all years of their programme. Although these sessions are formally timetabled for students, there are occasions when students lack the self-discipline and motivation to actively engage with this aspect of their professional development.

Our final year curriculum requires all students to complete an individual Final Year or Capstone Project (FYP). This is a significant undertaking for the student and although there is a less interventionist approach than that used in first year, by the end of their degree, all students will have scoped, planned and managed their own projects. They will have built on and honed those skills that they were introduced to at the start of their studies and that were built on in years 2 and 3 of their programmes. The FYP requires students to present their work at an exhibition or celebration event where they defend their approach to their FYP supervisors, general staff from the School, invited industrialists and industry-based FYP sponsors. This is organised in a similar way to a mini-engineering conference and provides students with another opportunity to develop their communication and presentational skills. Sponsorship of the event is normally provided by the professional bodies and from local employers. This is another example of the holistic approach taken by engineering course teams at Ulster in the development of our students' professional skills. It provides the University, students, the professional bodies and industry with opportunities for interaction and cooperation, which is mutually beneficial to all parties.

Table 2. Summary of student suggestions to enhance their employment prospects

Category	Terms used by students	First Year (% of total responses)	Final Year (% of total responses)
Industry-related	Visits to companies Industry case studies Course materials related to 'real world' Commercial context of engineering Guest speakers Industry-linked assignments/projects	20	30
Practical Skills	Practical/lab work Hands-on assignments Industry relevant software Problem-solving simulations Industry-relevant software	49	23
Communication skills	Oral Presentations Foreign language	9	2
Career planning	What do employers want Interview practice CV preparation Employer open days Encourage extra-curricular activities	3	34
Course-related	More short-term placements within course Facilitate summer placements Encourage membership of prof. bodies On-line resources	20	11

In essence our approach at Ulster is to introduce the concept of the engineer as a professional practitioner in the first year curriculum via a compulsory module dedicated specifically to soft skill development. The broad range of professional skills is then embedded within the discipline specific subject material that is required for year 2 and final year of professionally accredited honours degree programmes. Departments within the University but external to the School of Engineering promote extra-curricular activities that would further develop and enhance the soft skill set of the engineering students, although more work needs done to encourage engagement with these initiatives – as shown by the responses from final year students in Table 2.

4. Motivation of students in developing professional skills

As educators it is accepted that students will generally engage better with initiatives and activities that they enjoy. Students were asked to give their opinions on a range of teaching and assessment activities and the results are shown in Figure 3.

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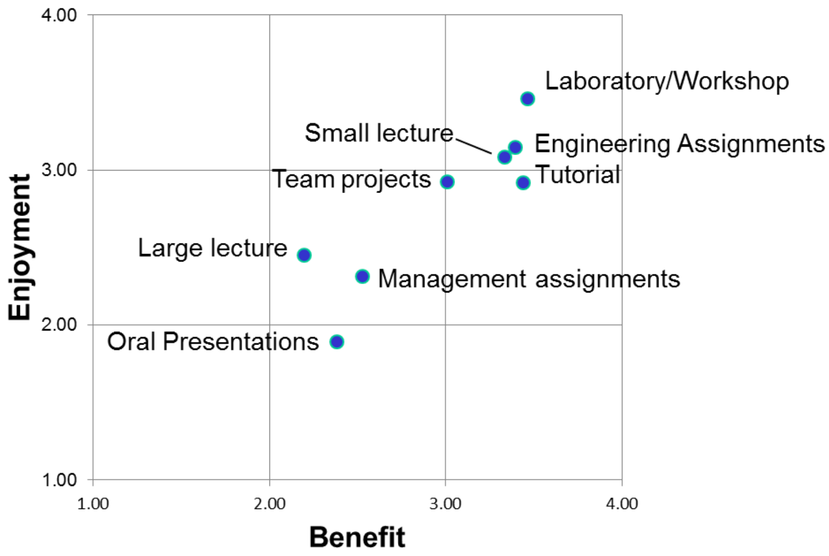

Figure 3. Student enjoyment – benefit matrix of learning opportunities

Students enjoy and feel that they benefit most by being taught in small lectures, doing assignments related to engineering and laboratory and workshop exercises. They do not enjoy or feel they benefit from large lectures: this is an area where course teams are seeking practical and cost effective solutions. Whilst students do not enjoy giving oral presentations, they recognize the benefit of this type of activity.

Figure 4 summarizes the extent to which the students believe their professional skills had been developed. Although students recognize that their skills have developed, interestingly there were no statistically significant differences between the year 1 and final year cohorts' self-evaluation. Self-assessment is recognized as requiring relatively sophisticated critical reflection and these skills develop during their studies. Consequently, the yardstick used by a typical first year student for the assessment of their skills is unlikely to be same as that used by a final year student. Cajander et al. reported similar findings and the results confirm the need for course teams to embed compulsory activities to develop students' professional skills throughout the duration of the course [17].

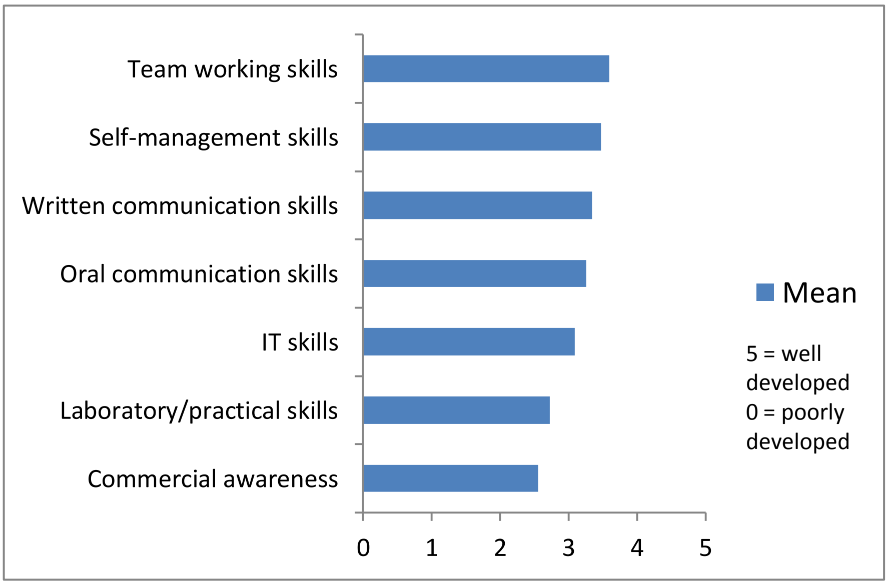

Figure 4. Student self-assessment of the development of professional skills

5. Conclusion

This paper describes a study that was conducted on first and final year students on the Mechanical Engineering and Engineering Management programmes at Ulster University. Results show that the students have a good understanding of what capabilities and skills engineering employers are looking for when they recruit graduates. First year students at Ulster are required to study a module that is specifically dedicated to the development of their soft or professional skills. In subsequent years of the programmes, course teams actively foster the development of professional skills by embedding them within programme modules. The on-going challenge for academics is to motivate students to capitalize on the range of developmental opportunities available in the co- and extra-curricular activities offered at institutional level, so that the already excellent employment rates can be further improved.

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Project Based Learning

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Comparing Characteristics of final projects: BSc students vs. Practical Engineering students – the supervisors' point of view

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Abstract

Many researchers mention various kind of project learning. Inquiry-based learning, product-based learning, project-oriented learning and project-based learning are among the various terms associated with project learning.
The two colleges in the common campus, the college of engineering and the college of practical engineering, carrying the similar name ORT Braude College (of engineering, or of practical engineering respectively), constituted a final project as an obligatory requirement for graduating. Although the degree of BSc is well recognized worldwide, the practical engineer degree needs to be explained as a degree on a higher level than a technician is but not as comprehensive academically as a BSc. The practical engineer degree requires two years of study after matriculation to complete.
An interesting aspect to investigate is a comparison of the quality between the populations in terms of their final projects. Seven supervisors, who instruct both BSc and practical engineering students during project work, were interviewed and the project books of their students were analysed. The preliminary results show that BSc students are required to explain their design considerations, such as why they choose a specific method and discuss other options. They had to determine the product specifications prior to starting to design and to verify reaching the exact specifications. In contrast, the practical engineering students are required to explain the principle of operation of their project, and to demonstrate that the product functions appropriately. An additional important finding is that BSc students initiate the project topic more frequently than the practical engineering students do.

Keywords: *Project learning, Engineering education, Final project.*

1. Introduction

On the campus of ORT Braude, Karmiel, Israel, are two educational institutions carrying the same name: the ORT Braude Academic College of Engineering and the ORT Braude College of Practical Engineering (PE). Both institutions have electrical engineering and electronics departments. Graduates of the academic college receive a BSc degree and the graduates of the Practical Engineering College receive a PE degree. A PE degree requires two years of study after completing the matriculation.

A final project is a mandatory requirement for graduation for both courses of study. Therefore, it is interesting to compare the accomplishments resulting from the project activity.

2. Literature review

Patton argued that project-based learning (PBL) refers to students designing, planning, and carrying out an extended project that produces a publicly exhibited output such as a product, publication, or presentation. Inquiry-based learning, product-based learning, project-oriented learning and project-based learning [1], "p.13" are among the terms related to PBL. Shekar states that project-based learning is essential to integrate the disciplines of design, marketing and manufacturing towards the common goal of creating a new product [2]. Engineering design is a central engineering activity [3]; therefore, it is very important to include it in undergraduate engineering curriculum [4] to help students to improve their academic achievement and skills and to develop high level thinking skills. During PBL, students are exposed to problem-solving and design activities which demand high level of thinking skills [3]. Project-based learning approach is useful because it "can provide students with real design experiences and opportunities to reflect on the design process" [5], "p. 749". Waks and Sabag showed that PE students who practice what they learned about digital electronics through project-based learning attained higher achievement levels in digital electronics compared to their peers who learned the conventional way [6]. Sabag, Trotskovsky and Waks explored the PBL environment and showed that PBL activities encourage students to reflect on their thinking [7],[8].

Integrating PBL into undergraduate curriculum in science and technology education, as described in [9], exposes students to the processes which are typical for engineering design. Meaning identification and analysis of requirements, collection and analysis of appropriate information, analyzing advantages and disadvantages and definition of alternative solutions, choosing the optimal solution, preliminary and detailed design, construction of a model or prototype and evaluation. When carrying out a design project, the students must see the final product (completed) and understand the relationships and effects among the product components.

Completing a final project is a mandatory requirement of the engineering curriculum at many academic institutions and colleges for practical engineering. At the end of the project activities, students must document their work and present the project at an evaluation forum.

Similarities and differences in various aspects of project implementation for BSc and PE students has not yet been researched. The current study aims at contributing to the knowledge in this area.

3. The research question

What are the accomplishments reached by students who perform final projects during their studies toward BSc in Electrical and Electronics Engineering compared with students who perform their final project in the framework of PE Electrical and Electronics, as seen from the supervisors' point of view?

4. Methodology

The objective of this paper is to compare the characteristics of engineering students' final project and PE students' final project. The study presented in this article used a qualitative approach, which was developed in the second half of the 20th century in social science disciplines such as sociology, anthropology and educational studies in order to understand students' behaviours and thinking processes [10]. The focus here is on interpretive research, which aims to understand and interpret actions, meanings, processes, and relationships of the investigated phenomenon [11].

4.1. Research tools

The research tools used for are in-depth interviews with supervisors and analysis of the project books that the students wrote as part of their project work.

4.2. Research population

The research population consisted of seven senior supervisors with professional experience ranging from 31 to 53 years. The supervisor with 31 years of professional experience has worked chiefly in the engineering design industry and two years in academia; he guided 10 students in the two institutions. The senior supervisor, who guided about 50 PE students and many BSc students in their final projects, has 53 year of professional experience, including 20 years in academia.

The book projects of more than 20 students were also analyzed.

5. Findings

5.1. Project books findings

Twenty project books, representing a random sample of hundreds projects books, were analyzed. Ten of them belong to PE students and ten to BSc students. Analyzing the projects' book revealed that the projects of the BSc students differ from the projects of the PE students. The comparison results are presented in Table 1:

Table 1. Comparison of PE students' project books with BSc students' projects books

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Characteristic	PE projects	BSc projects
Content	All projects are based on a micro-controller, or programmable array (FPGA), with some peripheral components, sensor and actuator or display. No innovation is expected.	The projects differ from one another. Some innovative thinking is expected (e.g., a monitor for home beer machine or a traffic-timing controller). Some projects deal with developing efficient algorithms for signal processing.
Specifications	None of the books included the specifications of the designed project.	Detailed specifications are frequently appear at the beginning of books. It is mandatory that the student confirm the project meets the specifications.
System thinking	There is no sign of system thinking. The books contain only explanations about how the components work, usually taken from the components' data sheets.	The system principal of operation is usually explained in the books. All the explanations are original work of the student.
Student tasks	There is no list of the student's tasks.	The student's tasks are detailed in the book. Moreover, the student is required to describe in the book how he/she fulfilled his/her tasks.
Debugging	There is no description of malfunction correction.	The student is required to describe in detail at least one or two cases of malfunction correction.

5.2. Findings from interviews with supervisors

All the interviewees are supervisors with rich experience in engineering design in industry and in academia. The cumulative number of students they guided during final projects reached into the hundreds. Therefore, it is essential to present the supervisors' point of view.

All the supervisors agreed that the nature of PE students' project is tangible, based on micro-controllers and peripherals, while the BSc project demands more theoretical background and might include newly acquired knowledge for both the student and the supervisor. Quotes from the interviews with supervisors support this assertion.

Ph. has 53 years of professional experience and 25 years in teaching. When asked to compare the nature of PE projects and BSc projects, he remarked:

> All the PE projects must be visible; they are mainly known control systems. On the other hand, the BSc projects deal with new knowledge; for example, the student who designed a cooling system based on a semiconductor device had to learn about the process first.

S. has 38 of experience in industry and teaching:

> When it comes to BSc students, I am ready to take a chance and start a project even though there is uncertainty or missing knowledge at the beginning; I don't dare to do this with PE students.

Initiating the project subject is the supervisor's role only in the case of PE projects. For BSc projects, many students initiate their own ideas. Moreover, in cases in which the supervisor suggests the project subject, the BSc students collaborate by suggesting their own ideas. The next quote illustrates this occurrence.

B. has 31 years of professional experience and two years of teaching:

> Initiating the project subject is mainly the supervisor's role. Lately, more and more BSc students respond to the challenge and initiate their own ideas.

Setting the project's specifications at the beginning and proving that the project meets them is mandatory for BSc students, but this is not required for PE students, as stated by **M.** (38 years of professional experience and 22 years of teaching).

M.: The BSc student defines the technical specifications with the supervisor's guidance, but in the case of the PE student, the supervisor defines the entire student's mission, usually not written in detail.

S.: Writing the project's specifications is a mandatory requirement for the BSc student, there is not such an obligation for PE students.

P. has 31 years of professional and 13 years of teaching experience:

BSc projects require predefined measurable and detailed specifications, but for PE projects, the specifications are flexible.

The BSc students' tasks are to design the entire project (software and hardware), assemble the circuits, locate and correct all malfunctions. The PE students' tasks are usually to assemble the circuits and, in the case of very evident malfunctions, to correct them. The expectation is that the supervisor will fix the more complicated malfunctions. The next quotations support this observation.

F. has 35 years of professional and 13 years of teaching experience:

The PE students do not design the electronic circuits; they get the schema from the supervisor and assemble the circuit.

E. has 35 years of professional and teaching experience:

The BSc student is required to design the hardware and software of the project, to compare alternatives and choose the best solution. The supervisor is there to guide the student and answer his/her questions. The PE student needs continuing guidance throughout the work.

Both PE and BSc students are required to document their project work. However, there are differences between documentation of these two populations. PE project books appear as a collection of component explanations, without a system approach and without design considerations; there are no descriptions of the student's work (e.g. malfunction corrections). On the other hand, BSc project books must reflect a system approach, including design considerations and design alternatives and at least two descriptions of malfunction corrections, as noted in the following statements.

B.: The BSc student has to write in detail about the design considerations, justify the decisions made, how the student has overcome the obstacles, as well as revisions done during the project work.

Ph.: The BSc student describes the engineering work done by him/her during the project work; nevertheless, the PE project's book is anecdotal.

S.: There is documentation of system considerations in the BSc project books but not in the PE project books; there you can find many detailed data sheets.

6. Conclusion

The final project is mandatory for BSc graduates as well as practical engineers. However, the roll of these two populations in industry is not the same. The BSc graduate frequently deals with engineering design in industry. The engineer's job involves specification of the technical characteristics of designed system, giving a considered opinion to selecting optimal solutions the designed system, verifying that the system meets the predefined specifications as well as assisting with documentation, which is very important to the firm where the engineer works.

The PE graduate usually work in maintenance or final test departments in industry. Therefore, the debugging qualifications are their main "working tools".

Based on the findings above, both from the project books and from the interviews with the supervisors, it can be claimed that the BSc projects are well oriented to prepare the students for their future work in industry. Nevertheless, it is suggested that the PE College should be consistent in requiring the students to perform malfunction debugging with less reliance on supervisors'. Improving the documentation is also advised.

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The importance of criticality in (project management) competence research

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Abstract

Six focus groups discussed various instances of criticality: in which processes is the presence of the project manager critical and what are the critical competences for a project manager. The results on processes show agreement on subject groups and processes. The results on critical competences show less agreement. There is a big difference in the distribution of critical competences compared to found important competences in recent publications. The competences in recent publications lack the specificity to create a comparison with the results of the focus groups on competence level. Although finding some examples, there is not enough material to prove or disprove the hypothesis that adding criticality to competence research is needed to reveal the essence of project management.

Keywords: *project management, competences, criticality, processes, subject groups.*

1. Introduction

There is little agreement among educators and training program directors of many leading universities and institutions on what makes a good project manager [1]. There is a risk of a widening lack of understanding between the industrial stakeholders, the researchers, teachers, consultants and professional associations, about teaching and learning of project management [2]. Although the numbers vary geographically, a vast majority of project managers has a higher education degree [3], explaining why several higher education institutions like in Engineering, Construction and Information and Communication Technology (ICT) feel a need to teach their students project management [4-9]. But project management encompasses a very diverse set of competences with limits to the amount of time that can be dedicated to project management [10]. Recent research on project management competences does not create a clear picture for educational focus [11].
To provide clarity a taxonomy for identifying key educational challenges for project management education is proposed [12,13], that builds on a validated taxonomy for management competences [14,15]. This new taxonomy can be used to aggregate recent research on project management competences. However, it is also argued that recent research, which is often lacking a focus on competences that are critical for project management, could obscure the essence of project management [13]. In the presented research we test this hypothesis by discussing the essence of project management with six focus groups [16,17] of experienced project managers in various industries.

2. Recent research and criticality

Critical competences are defined as the competences a project manager needs to have to be able to function as a project manager, as opposed to what a non-project manager needs to have in the same context. In operational sense this could be defined as the competences on which a project manager needs to be better than others (in the project team) in order to function as such.

Examples of these critical competences are mostly found in opinionating articles which advocate a higher emphasis on (political) communication [18] suggest that project managers should not wait for sufficient top management support [19] or promote a focus on people skills [20].

Twenty-five recent publications have identified (important) competences for project management [12]. A significant part of the competences researched can be positioned in a general skills domain. General in this context is defined as competences that are of a general nature, not specifically project management related, and are expected of any higher education graduate. Examples are communication, basic computer and analytical skills. In these publications there has not been a stringent focus on critical as defined here, leading to effects like

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all researched competences are important or very important [21] for a project manager or basic computers skills is the highest ranking competence for a project manager [22].

(Higher) Education plays an important role in preparing future project leaders for their task [10,23-25]. Given that the room in higher education curricula to develop project management competences is limited [10], we argue that the development should be focused on critical competences. In order to define these critical competences, one needs to know which (project management) processes are critical.

3. Research method

We used focus groups [16,17] to explore the concept of criticality in project management, from the perspective of the experienced project manager. Participants shared thoughts and interacted on the subject. This method not only helps to generate ideas but could also assist in anchoring peoples thoughts on competences[26]. Participants were asked to prepare for the session by selecting a maximum of five processes from the ISO table of project management processes cross-referenced to process and subject groups [27] or naming one or more own processes in which they deemed the presence of the project manager to be of critical importance. After a short introduction of the research, the group session was started by discussing the question 'do you experience differences in qualities between project managers (yourself) and project members?'. Usually interaction on this question lasted for about an hour and then continued onto the next question 'are these differences in line with the expectations on project managers?'. The interaction on this question usually lasted another fifteen to thirty minutes. We then asked each individual to first select and then name his or her five critical processes, allowing them to select a complete cell of processes from the ISO table [27]. Most participants selected their top five after the discussion. After a brief discussion on the resulting matrix we asked every participant to individually mark all competences they thought they were better at then others, bearing criticality in mind, on a constructed list of all potential project management competences [13]. Both the selection of processes and competences were purposefully done individually to ensure an equal contribution of all individual participants [26]. A brief overview of notes taken during the discussion, the resulting matrix and the group results on the competences was sent to the participants, usually within a week.

This process has been repeated six times with six different focus groups, totaling 44 participants. The data consists of notes taken by the researcher during the focus group discussion, recordings of the discussion, participant forms on their background, the matrix of critical processes constructed with each group and the individual surveys with competences. In this paper we report on the analysis of participant forms, the matrices, the individual surveys and the notes.

The smallest group consisted of five members, the biggest counted eleven participants. Two of the six groups could be considered company groups, in which all participants were working for the same company (numbers 1 and 4). Another one was a group of project managers that had a long tradition of coming together to discuss shared topics (number 2). The other three groups consisted of project managers that volunteered for an open session, one totally open (number 3) and the other two consisting of project managers that shared a common education curriculum set up for project managers working in governmental based projects (numbers 5 and 6).

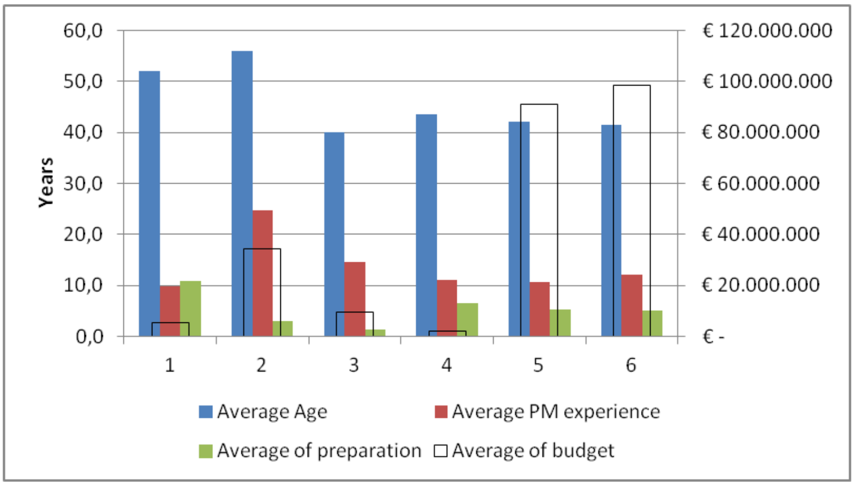

Figure 1. Graphical representation of focus groups on various descriptive factors

Although the last two groups accounted for 30% of the participants, the resulting distribution of critical process groups in the matrix changed hardly (changes within 2%), therefore suggesting convergence of the group results [17]. The six groups differed on average years of experience as a project manager, years spent in projects before becoming a project manager, budget on projects and somewhat on average age. See figure 1 for an illustration. Apart from this, the groups also differed on the type of projects the participants had experience in, showing more but not total similarity on project phase experience, as illustrated in figures 2 and 3.

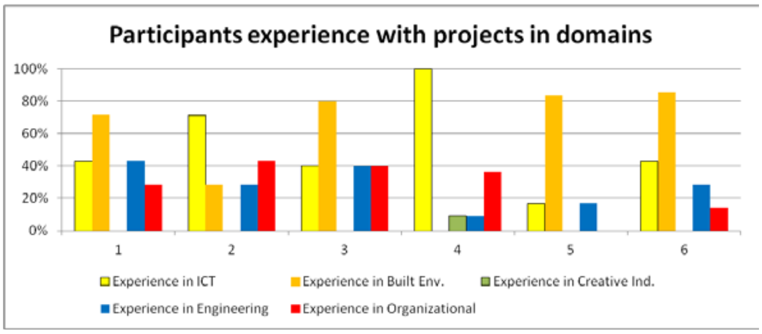

Figure 2. Graphical representation of participants versus project domains

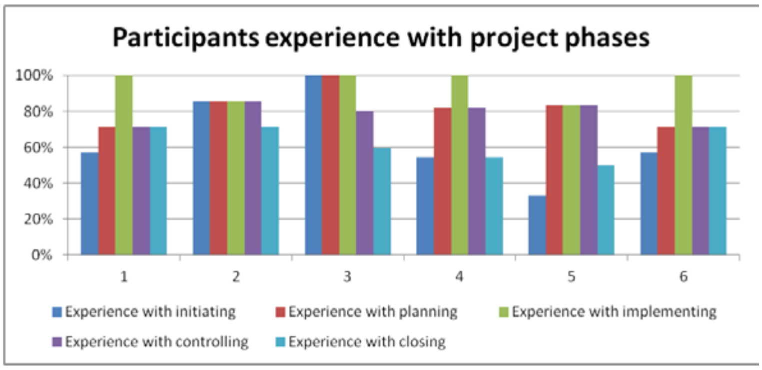

Figure 3. Graphical representation of participants versus process groups

4. Focus group results

Five groups selected only cells or processes in the supplied ISO table project processes, which is a matrix of five process groups and ten subject groups, containing 39 processes which are not equally distributed over the matrix [27]. One group suggested an addition on the cross reference table: value management.

Of the process groups controlling (69 votes), planning (60) and implementing (64) were favored over initiating (20) and closing (0). When looking at the relative importance (since initiating has only three processes compared to the sixteen of planning) the order becomes implementing, initiating, controlling, planning.

Defining a positive score when a focus group placed more than 15% of their votes in a specific subject group and a negative score when this was less than 5%, we observe that most subjects score mixed, as illustrated in table 1. We can also observe that although there are differences in the way the subjects are scored per group, there does not appear to be a large discrepancy in the way the subject groups are valued to be critical.

Stakeholder scores positive in all focus groups, procurement scores negative in all focus groups. Value is mentioned by only one group and scores in the middle category. The subject groups can be ordered based on this scoring from most to least critical: stakeholder, resource, scope, communication, risk, integration - all on positive scoring side, value (zero), cost and time, quality and procurement . Looking at total scores the lagging subjects are also cost (11), time (8), quality (5) and procurement (2). Even looking at relative scoring the iron triangle of project management (cost, time, quality) again falls in the low scoring section with procurement and (surprisingly) integration. Integration falls into the least scoring category because of the high number of processes (7). Discussion in the groups revealed that the subject groups cost, time and quality were not deemed unimportant, but that initiating, planning and controlling them were processes where a project manager would not be considered critical. These processes could be delegated.

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Table 1. scoring the subject groups

	Focus group					
Subject	1	2	3	4	5	6
Communication	0	+	+	0	0	+
Cost	0	-	-	0	-	-
Integration	0	+	0	0	0	0
Procurement	-	-	-	-	-	-
Quality	0	-	-	-	-	-
Resource	+	0	+	+	+	+
Risk	0	+	0	0	+	0
Scope	+	+	0	+	0	+
Stakeholder	+	+	+	+	+	+
Time	0	-	-	0	-	-
Value			0			

Of the 39 processes five received no votes, three only received indirect votes (when the grid position in the matrix was selected). The remaining 31 received between one and 33 votes. The top scoring eleven (9, 10 and 11 all scored the same) and those mentioned in at least four groups are (in descending order) stakeholder management, define scope, develop project team, manage communications, control scope, identify risks, control risks, identify stakeholders, manage project team, develop project charter, direct project work, control changes, establish project team, develop budget, treat risks and plan communications as illustrated in figure 4. Discussion in the groups revealed that in several cases there was a difference of interpretation. Some participants chose treat risks with the same explanations as others chose control risks. The same interpretation differences occurred between develop, establish and manage project team. Taking this into account, managing stakeholders still remains the foremost critical, followed by project team (developing & establishing), defining scope and communications. Risk (identifying, control and treat) also forms an important critical cluster. This is in agreement with the ordering based on the scoring of subject groups.

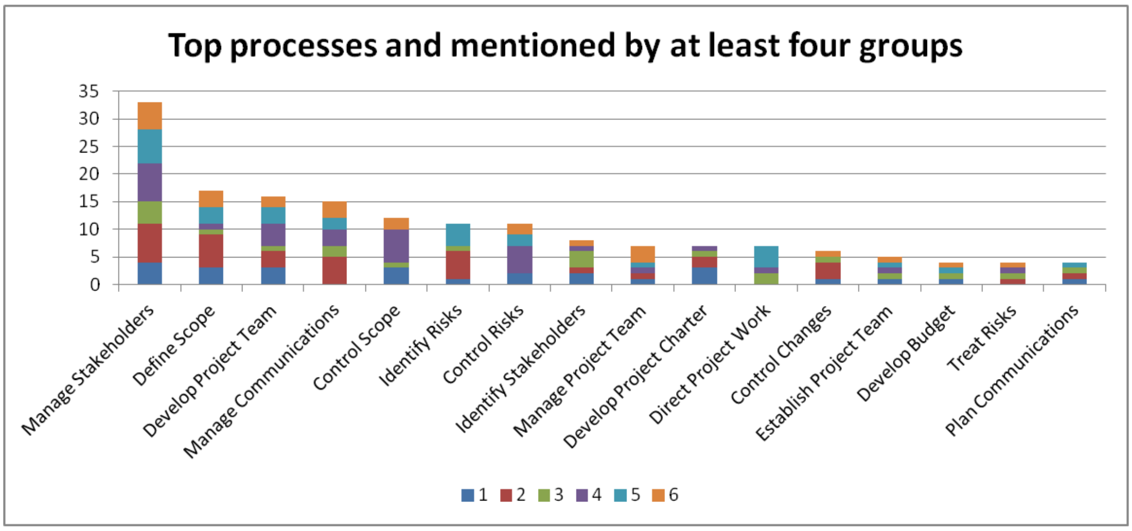

Figure 4. Best scoring processes (by number and groups mentioning)

With discussions on differing qualities, expectations on project managers and processes where project managers played critical roles as preparation, participants were asked to scan a competence list containing eleven domains containing 75 competences [13] and mark individually those competences in which they considered themselves to out qualify project team members. This took most of them about five minutes to do. The percentage of marked competences does not show a relation with the group number. Overall 37,8 percent of the list is marked.

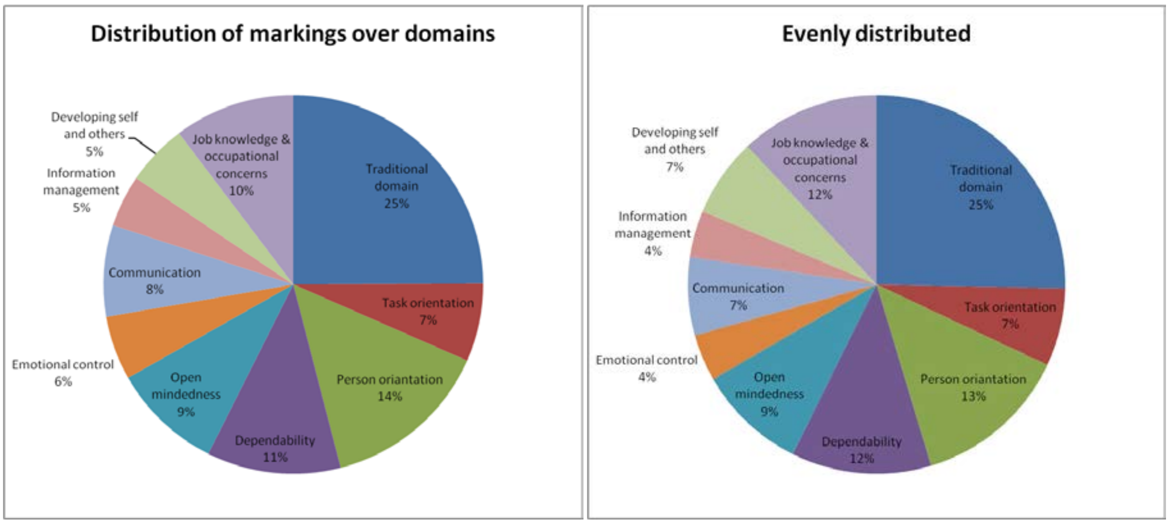

Figure 5a and 5b. Distribution of markings of participants and all choices per domain

The distribution of markings over the domains showed a high similarity with the distribution of competences of the domains as shown in figures 5a and 5b. Emotional control gets a relative high marking, with an average of 52% of the potential markings (competences in this domain multiplied with the number of participants). Developing self and others gets a relative low marking, with 30% marked of the potential markings.

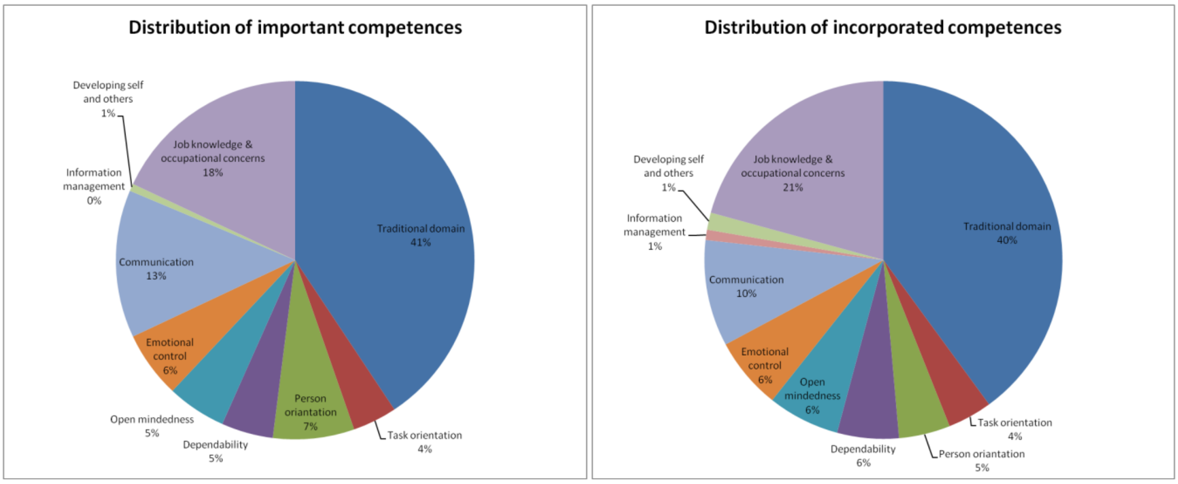

Figure 6a and 6b. Distribution of important and incorporate competences in the aggregation of recent literature

Mapping recent publications onto the same taxonomy of project management competences and focusing on important competences displays a different distribution. There is much more focus on traditional functions, job knowledge & occupational concerns and communications[13] as shown in figures 6a and 6b. This is partly due to the incorporated competences in the research for these publications, and the fluctuation of the portion of competences that are found important relative to incorporated between 38% and 73%[13] a bigger fluctuation than encountered in the focus groups.

This bigger fluctuation is partly explained by what is asked. Several competences incorporated are of a broad overall nature, like communication versus the breakdown used in the taxonomy of listening skills, oral communication, public presentation and written communication. The domains with a relatively high fraction of important competences show also a high fraction of competences with an overall nature [13]. Moreover the majority of publications were not based on questioning whether a competence was important relative to others as specifically done in our research. A few results illustrate this effect, like short term planning with a score of 44% importance, scoring only 7% in our research. Other such examples are financial concern (50% versus 25%) and monitoring (38% versus 16%). All three illustrate competences that could be considered of universal importance for all kinds of professions including project team members. Our participants were asked to make this distinction.

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Some competences score relatively high, others relatively low, but all score between 5% and 73%. The competences that receive the highest markings (cut off: 55%) - we will call them critical - are in given in order of the survey in table 2, with percentages of publications finding this important. We note that some publications not only incorporate positively formulated competences but negative ones as well like defensive or evasive. We also note that only very few of the found competences find several counterparts in recent research.

Table 2. Critical competences compared to recent research

Critical competences (%marked)	% important	In recent publications # important	# incorporated (publications)
Motivating by persuasion (59%)	20%	1	5
Team building (57%)	55%	6	12 (11)
Natural leadership (61%)	93%	13	14
Expectation management (61%)	20%	1	5
Initiative (59%)	60%	3	5
Decisiveness (57%)	50%	1	2
Cooperation (57%)	-	0	0
Political astuteness (64%)	50%	1	2
Assertiveness (59%)	-	0	0
People reading (57%)	-	0	0
Approachability (55%)	-	0	0
Personal responsibility (73%)	100%	1	1
Trustworthiness (59%)	80%	4	6 (5)
Analytical thinking (61%)	60%	3	5
Composure [under stress] (59%)	33%	2	10 (6)
Resilience (55%)	50%	2	4
Listening (64%)	67%	2	3
Position knowledge (57%)	63%	5	10 (8)
Organization awareness (64%)	40%	2	8 (5)

From the notes taken a similar picture appears with references (in brackets the group numbers) among others to team building (1,2,3,4,5), decisiveness (1,3,4,6), risk management (1,2,5,6), person orientation (1,3,5,6), task orientation (1,2,5), strategic planning (1,2,6), influencing (1,3,4,5), personal responsibility (2,3,4,6), stakeholder management (3,5), company concerns (3,4,5,6), political astuteness (3,4,6), people reading (3,5) and listening skills (4,5,6).

When we look at the top marked competences from the participants in focus groups, the often broad nature of the competences in recent research hinders a good comparison. Only two of listed critical competences have been incorporated in ten or more publications. One is natural leadership, derived from leadership as used in recent research but not referring to the same kind of competence[13], the other one is team building, incorporated twelve times in eleven publications and found to be important in six which is comparable to our 57%. A desirable overall comparison between our results with project managers focused on criticality and the aggregation of recent literature cannot be made on competence level.

5. Discussion

Our research was Dutch based only and the recent publications used are not geographically limited to the same area. Geographical differences have been shown in relation to project success [28], so different views on competences could occur, limiting the generalization of any conclusion.

Although we accumulated over five hundred years of project experience in this study, it still remains a qualitative study, aimed at finding critical processes for project managers. Conclusions can only be suggestions and need to be tested more quantitatively.

The use of a taxonomy for project management competences facilitates the comparison with contemporary research. Simply adding recent publications in order to find important competences does not do the difference in

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number of respondents nor the number of incorporated competences of them justice. We argue that an intricate system with factors will not solve the signaled use of general and overall competences.

We compared the marked competences with the notes by the researcher. There is a change of researcher bias [17] which can be solved by using the recordings, which we did not do.

We wanted the participants to rate themselves on a list of competences in relation to project team members bearing in mind the critical processes discussed previously. This is a difficult question with a high risk that a simpler question is answered [26]. This risk is apparent since most of them took around five minutes to rate the list (15 competences per minute = four.

Focusing on critical processes and competences could benefit higher education into finding a focus for their efforts in developing project management competences, but we discussed these with experienced project managers. Their focus could be very different as opposed to fresh project managers.

6. Conclusions and suggestions

This research has shown that experienced project managers - in the Dutch area - share processes they consider to be critical. There is an ordering of subject groups possible, with the most critical of them being (in descending order) stakeholder, resource, scope, communication, risk, integration. Risk management is voted by most as an critical process.

When asked in which competences the project managers perform better in relation to team members, a distinction between high scoring and low scoring competences can be made, but a clear selection of specific competences is not found. The higher scoring competences resemble the competences noted in the first part of the discussion. Further research on the recordings could support this conclusion.

The distribution of competences over the domains of the used taxonomy shows a remarkable difference with the mapping of recent publications onto the same taxonomy. The aggregation also shows a higher fluctuation than the results of our participants, with causes in the use of general and overall competences instead of the more specific formulated competences of the taxonomy. This lacking of specificity makes a comparison on competence level difficult, only a few examples could be found to support our hypothesis that adding criticality would better reveal the essence of project management. Although we did find some examples, in the end there is just not enough material to support or dismiss the hypothesis.

Using a taxonomy for future research would benefit the comparison of research efforts.

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Measuring learning gains in project management

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Abstract

Teaching project management is becoming a standard part of curricula in higher education. Assessing the added value of the teaching efforts needs pre- and post assessments. Given the wide variety of skills and knowledge project management embraces a proper assessment of project management is difficult. A method of assessing added value has been designed and tested on the first part of a professional Master in Project and Process Management. The design is based on students assessment of learning gains (SALG) with several extra criteria. The design was evaluated, updated and tested again. The third test with a tweaked design is being performed. The results do not convince that this SALG-based instrument can be used to measure added value.

Keywords: *project management, added value, measuring, education, students assessment of learning gains.*

1. Introduction

Crawford, Morris, Thomas, and Winter [1] state: ‘Project management is offered as a significant component in a range of undergraduate and postgraduate academic qualifications, including construction, engineering and IT,’ which is in line with the desire to make the higher education studies more relevant to daily work practice [2]. Martin [3] claims that project management is an important element of both management and engineering education. But incorporating project management is not easy, as Ellis, Thorpe and Wood [4] note: ‘Project management is a challenging subject to deliver, not least because of the wide variety of skills and knowledge it embraces.’ Michel and Prévôt [5] note that more emphasis should be placed on soft skills such as social, emotional and organizational.

There is a great variety of suggested ways to convey project management competences: simulation training, service learning, PBL, PBL with a project manager from a different study, case study, etc (see [6] for a more extensive list of literature). Most of these alternatives are not evaluated on the success of the pedagogical approach, but by means of student enthusiasm (‘I learned a lot’) and/or 'ticking off' products (planning, report).

Measuring and evaluating the success of a pedagogical approach /…/ is crucial as it allows one to determine if the given approach is indeed effective, with objective measures to accompany the claim [7]. Although assessment has been implemented for a long time in project management [8], it is found to be a difficult task to perform correctly in higher education [9]. The required behavioral skills … are difficult to assess and innovative approaches are required [10]. It can be argued that assessing competences of project managers is already available for certification purposes, but those assessments are targeted at project managers with experience and not at student level or are aimed at the knowledge component only. A link between these certification systems and achieving project success is almost nonexistent [11,12].

Measuring learning outcome is not sufficient for evaluating teaching efforts, we need to assess added value to evaluate the teaching efforts, as the incoming ability is the largest predictor of the outcome ability [13].

A relative simple form of a performance test is a 360 degrees feedback system where the student is evaluated by a group of peers. In new groups, where students do not have ample previous experience with each other a 360 degrees feedback system will not be able to produces a pre-test and therefore will not be able to measure learning gains. Moreover peer performance test can suffer from a halo effect [14]. More elaborate performance tests (like role play or expert assessment) have the disadvantage of being labor and/or money intensive [15,16].

In this paper we report on design research [17], aimed at using Students Assessments of Learning Gains (SALG) [18], in order to measure learning gains in a professional Master of Project and Process Management. The design has been tested and evaluated twice and is being performed on the third group of students.

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First we introduce the design criteria for using SALG, secondly we describe the case study and thirdly we describe the tests and evaluations. Limitations are discussed before we reach a preliminary conclusion.

2. Assessment of learning gains

Considering that most higher education institutions do not have an infinite funding, a labor intensive assessment for a pre- and posttest will usually not be used to measure learning gains, and this is reflected in literature where various researchers turn to SALG [7,18-22] to illustrate or claim teaching effects. There is a difference in how SALG is used. Most don't use a pretest, some ask students what activities helped the learning process [20] and some ask students their perceived learning gains in a posttest [19,22]. SALG does have a big weakness, since it is self assessment. But 'though it has some limitations [it] may be used as part of a multi-source evaluation scheme' [23]. They go on to conclude 'Most studies of self-assessment are in areas of technical knowledge and ability. Even in concrete areas such as these, self-assessment has been found to be inaccurate'. Noting this risk, we will develop design criteria for using SALG to assess added value.

Kirkpatrick [24-26] gives a four level model of evaluation. The first level is how the students value the direct experience - also known as the smile sheet -, the second level measures the direct learning effect, the third level tests if a permanent learning effect has occurred and the fourth level looks for the added value in the workplace. The second level compares to the desire to evaluate the teaching effects. Kirkpatrick argues that measuring the second level can only be done if the first level is measured, and that the second level needs a pre- and posttest (criterion 1).

Using student assessment, they can be asked to assess their own ability to perform a task. Since students could be without experience, it would be better to ask students for their perceived ability (design criterion 2).

A weakness of SALG is the self evaluation factor as mentioned before. We will work on the premise that when self-assessment is used in a pre- and posttest, with the same scales, the only thing that is measured is the gain. This does require experience of the student in the subject of self assessment. If a student has never made a planning for a project before, the pre-self-assessment of a student's ability to make a planning could give inaccurate results. We have to compensate for this effect, which has to do with the students relative position on four stages in the learning cycle [27]. One usually starts in stage one: unconscious incompetent. The next stage is described as conscious incompetent, also referred to as 'you know that you don't know'. The following stages are conscious competent and unconscious competent. Going from stage one to stage two is learning, detecting this in a pre- and posttest on perceived ability poses a challenge, since it could cause the perceived ability to decline. The design of an instrument to test added value will have to account for this effect (design criterion 3).

Another challenge is the effect of students not completing the whole course and therefore not handing in a posttest. A level of attrition of 25% is not uncommon [7], which poses a challenge for the evaluation of the results. It is argued that given described uncertainties in self assessment it is unwise to compare pretest and posttest results without accounting for the attrition (design criterion 4).

Concluding, our design criteria for using SALG to assess added value are:

1. Use pre- and posttest
2. Use perceived ability
3. Account for learning stage one
4. Account for attrition

The effect of the learning cycle can be countered by asking the student for their perceived ability in the pretest and asking on what experience this perceived ability is based. Posttest results of students with no previous experience should be scrutinized for the reported difference in their perceived ability. To achieve this, it should be possible to link the pre- and posttest on an individual basis.

Linking the pre- and posttest on an individual basis provides an opportunity to account for attrition. Pretests of students without posttests should be discarded for the evaluation of added value.

The design proposal for using of SALG is therefore: a pretest which asks students about their previous experience with the subjects and asks their perceived ability on thes subjects. A posttest asks students again for their previous experience (in order to link them) and their (new) perceived ability on the subjects.

3. The case of a professional Master in Project and Process Management

All tests have been performed on the first seven months of a professional Masters program (420 student study hours), in which only students with relevant working experience are allowed. The first part of the Master of Project and Process Management in the Green Environment at Van Hall Larenstein focuses on soft skill development with coaches and actors, lectures on project management subjects and a complex group project. The complexity of this project is created by having the group find a project sponsor which was willing to let them work on a 'non undisputed problem'. In other words, the project has to involve some kind of controversy like conflicting stakeholders or failed first attempts. The soft skills development is on individual and group basis, particularly on personal effectiveness. The lectures on project management subjects host a mix of scientific publications, project management methods, process management approaches, theoretical exercises and group reflection on the group project relating to the theory.

Looking at the primary goals of the Master, a fitting performance test would be if students would be able to handle stakeholder conflict situations (of a professional nature), to produce project plans which would contain acceptable steps for all stakeholders, to execute and close a project according to plan while performing adequate risk management and to be able to build and maintain a project team. This description explains the choice of 'non disputed problem'. It also provides clues why a performance assessment as a pretest would be difficult in areas like executing a project (requiring time), adequate risk management, handling conflict situations (both requiring realistic situations) and building teams (requiring time and a team).

The first case study had ten students, working in two teams on separate projects with nine students finishing. The second case study had seven students with seven finishing, working in one team. The third case study had eight students split on two projects, number of finishing unknown yet.

The students met every week for skills training and lectures for two consecutive days, and were asked at the end of every day to reflect on the quality of the day (like: quality of the teaching staff, quality of interaction etc.), therefore accounting for the level 1 measurement. Teaching staff was informed of their performance and if necessary changed their approach based on these level 1 measurements. A short level 2 measurement was performed at the end of each lecture day by asking each of the students to describe in a few words what they learned. The teams also met for meet twice for a whole week to work on the project.

Since the primary author was a lecturer in this Master, there was a stringent focus on anonymity of the students participating in the research to avoid student and or researcher bias. Assessment forms were handed out and collected by others than the researcher.

4. Testing design one

The survey pretest asked for experience (working in projects, leading projects, sponsoring project), trust in knowledge (theory, methods and techniques) and trust in skills (starting a project, executing a project, bringing a project to an end and closing a project). The trust questions were given a five point Likert scale ranging from no trust to high trust. The experience was given a four point Likert scale ranging from none to experienced (more than five projects). When experience was claimed the student had to fill in the turnover of the most recent project. The pretest was handed out and filled in at the kickoff session of the program.

The posttest survey asked the same questions, and asked students where they perceived their learning gains (subjects project communication, leading projects, planning and monitoring projects, people skills, risk management, negotiation skills, decisiveness, team building, industry specific and project management methods and techniques based on the top ten competences derived from research [28]), in a three point Likert scale ranging from no progress to considerable progress. It also hosted a not applicable option. Industry specific means knowledge in their own domain, a 'control question' since specific attention on this subject was not featured in the courses. The posttest was supposed to be handed out and filled in at the closing session of the first part of the program, but was sent by e-mail afterwards instead.

The survey forms were not coded to an individual student, but asked their experience twice. Although the sample was small, it was not possible to link all posttest surveys to the pretest surveys. Six students returned the posttest, four could be linked to the pretest. We briefly describe their results.

Student 1: experienced project manager. This student reports a gain in trust on all three knowledge areas with one point and on two of the four skills, also with one point. This student reports some perceived progress on

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leading projects, own domain and project management methods and techniques) and considerable progress on people skills and team building. There was no perceived progress on the other subjects.

Student 2: experienced project manager. This student reports a gain in trust in knowledge, theory but a loss in trust in knowledge of techniques (both one point). No gain or loss was reported on trust in skills. The student did not complete the perceived progress part of the survey.

Student 3: inexperienced project manager. This student reports a knowledge trust gain on theory and on skills in executing a project (both one point). On perceived gains, this student reports no progress on negotiation skills, but some or considerable progress on all other subjects (considerable on project communication, planning and monitoring and own domain).

Student 4: experienced project manager. This student reports knowledge gains on all three knowledge areas (one point) and a loss of trust in skills on starting a project (from highly confident to confident). This student reports a perceived progress on all subjects, some progress on planning and monitoring and on decisiveness, the rest is reported as considerable progress.

No student reports a big change in their trust level. The reported changes could be attributed to different causes, with education being only one of them. It could also be respondent error, since asking for trust is a subjective measurement and small changes could occur depending on the respondents well being. The reported perceived gain shows a much more pronounced result than the trust questions.

Remarkable is that a experienced project manager (student 4) reports more perceived gains than the inexperienced project manager (student 3), which is in contrast to what could be expected. The causes of this unexpected result can only be speculated. Another experienced project manager (student 1) reports much less perceived gain.

5. Improved design and second test

Students numbers were introduced, linking pre- and posttest. The section of perceived gains was introduced into the pretest as a perceived ability. The perceived gains remained in the posttest, but a comparable perceived ability was introduced. The most important change however is the introduction of a 360 degrees feedback system. The students were evaluated by two peers and the coordinator and skills trainer (primary author is not the trainer). Students and trainers got acquainted with each other (that is a study week of working experience in their project) before this pre-test was taken. The self assessment pretest was taken in the first week of the program.

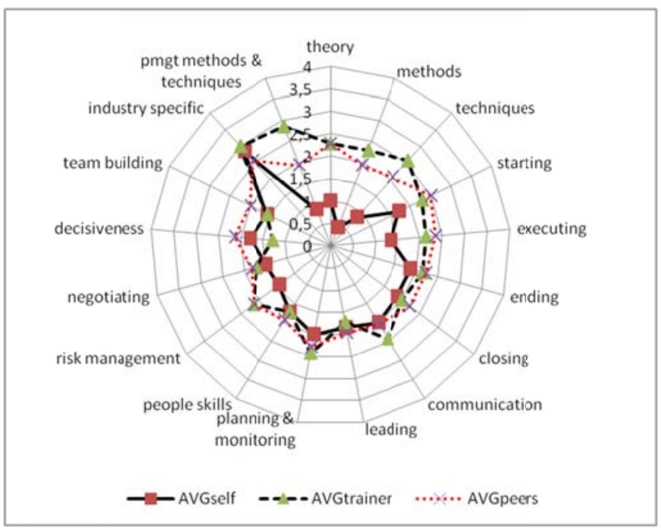

Figure 1. Comparing initial self, peer and trainer appraisal

There are seven participants in the Master. Two experienced students, two moderately experienced students and three students with little or no project management experience (although they all have project membership experience). The pre-test shows a that on average the students value their knowledge of project management theory, methods and techniques to be low while their peers and trainer value them much higher on the same scale. Lesser differences but sharing the same image are risk management, starting and executing projects. On the other questions there appears to be a congruent picture – on average. Almost all points of measurement are lower in the self-evaluation than that of peer or trainer evaluation (see figure 1 for an illustration).

Greater differences of level evaluation are mostly seen in the abstract first part of the questionnaire (theory, methods, techniques, starting, executing, ending & closing and the last question: knowledge of pmgt methods and techniques. Precisely in these parts the self-assessment reports the highest gains. The before and after comparison of the trainer and the peers show much more moderate differences with the initial appraisal. See figures 2a, b and c

Figure 2a, b and c: comparing pre and post from self (a), trainer (b) and peer assessment (c)

It is tempting to conclude from these results that self-assessment is the least reliable instrument. Especially when noted that on average the project management methods and techniques get very little attention in the researched period. There is much more attention on interpersonal competences. Not graphically displayed, but comparing on the more abstract knowledge (theory, methods and techniques) and ability subjects (starting, executing, ending and closing), only self assessment shows a more than 'respondent error' effect. Self assessment is consistently more positive than peer or trainer assessment on these subjects.

Comparing claimed learning effect versus the difference in assessed levels, the average scores of the students show a high level of congruence, as do the scores of the peers. The scores of the trainer show less congruence. On three occasions the change in average confidence level of the trainer is almost zero (planning & monitoring, industry specific and project management methods & techniques) while the average claimed learning effect is high. The confidence assessment looks more reliable in this case as it has been argued before that last two fields receive very little attention so a high learning effect is improbable. This does not explain the difference on planning & monitoring though.

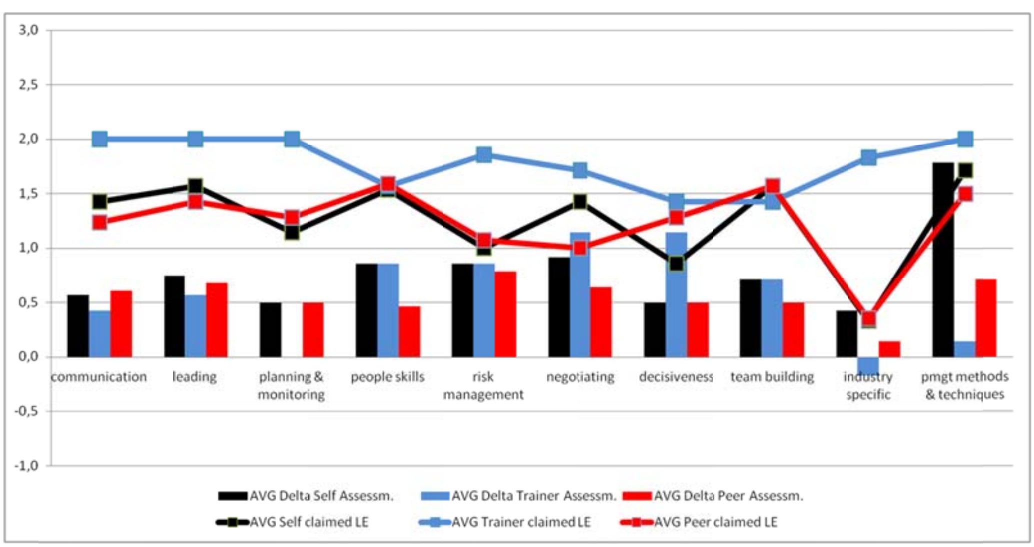

Figure 3. Comparing averages assessed and claimed learning effects on subjects

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Comparing the results of students, peers and trainers on learning effect or on difference (delta) on confidence levels, the latter shows agreement among the three groups. Which is strange because of the before noted temptation to discount self-assessment. The self-assessed learning effect and the peer-assessed learning effect also show agreement and a sort of disagreement with the learning effects claimed by the trainer. See figure 3 for an illustration.

The results are at least confusing. Looking at averages, the self-assessment appears to be the least reliable, but does show a reasonable agreement with peer- and trainer-assessment. The arguably less reliable learning effect claim shows better congruence albeit only between self and peer evaluation. This could support a conclusion that both are not reliable.

Looking from a different perspective, which student learned most, reveals that even on this level there is no agreement. Best student - the one with the highest 'added value' - according to self assessment is #4, while self claimed #5 is the best student, trainer assessments reveals #1 to be best which is tied best with #3 on trainer claimed. Peers assess #5 to be the best student and claim #3 to be the best student, as illustrated in figure 4.

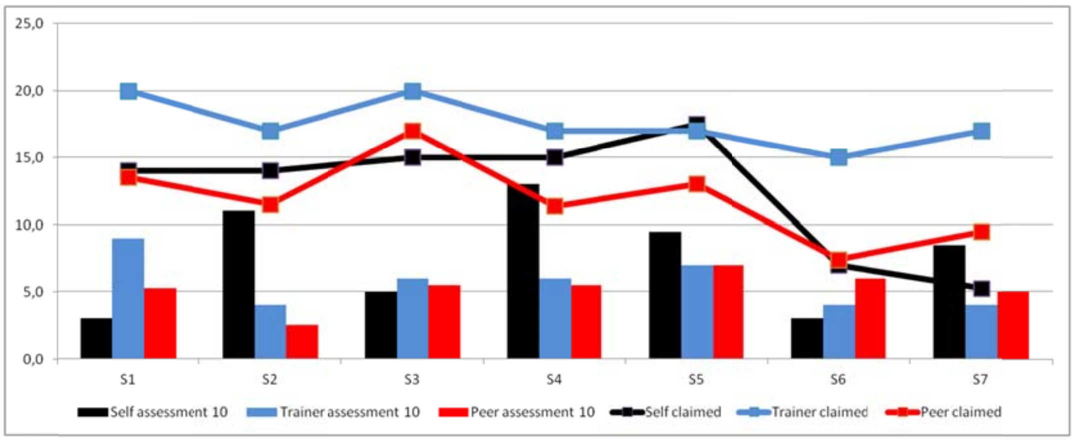

Figure 4. Comparing averages assessed and claimed learning effects on student level

On average all measurements do suggest added value. This changes at student level, where several subjects show a negative assessed gain or a higher assessed gain than claimed and quite often disagreement between the assessed learning effect from different assessor groups (self, peer, trainer) ranging from negative to positive. These effects are not linked to specific subjects or specific assessor groups.

6. Tweaked design and third test

The third design in our research will add a few extra's in the posttest: It will feature a election of the best student: which of the students is (self, peer and trainer) assessed to be best in project management (ordering of all the students). This will be compared with an actual individual assessment of all students. This third design will again be tested on the Master of Project and Process Management, the pretest has been performed. This time the pretest has been issued not directly at the start of the course but after a few weeks. As usual, the peer and trainer assessment was done after the first project week. The average appraisal bears a great similarity with the average appraisal of the second test. The posttest will be performed in the beginning of July 2015. Although not expected, the results of this test could lead to changes in the discussion and conclusions session.

7. Discussion

The first test did not provide clues that any of the two types of measurements (SALG with difference in confidence level and SALG with claimed learning effects) could be a valid representation of learning gains. Introducing peer and trainer assessment did solve the issue of correctly linking pre- and posttest, but did not provide extra clues whether any of the measurements could serve as a valid representation of learning gains. Overall students and peers claim learning effects which are notably higher than comparing perceived ability.

The control question - industry specific - does lead to a negligent effect in the second test, only trainer claimed shows an average learning effect. If we take the small but positive effect as an indication of no learning, comparing the averages shows possible learning in self assessed on the topics of people skills, risk management and negotiating an even less likely on team building and leading. The only convincing topic being project methods and techniques. Because of this result, self assessment is discounted as method. Self claimed is discounted based on the results of the first test.

Claimed effects are almost consistently higher than assessed effects, not only by students self, but also by peers and notably by the trainer. The claimed effects are sometimes high on subjects where was expected nor logical (like project management methods and techniques and leading projects) and sometimes high on subjects where it was expected and logical (like team building and people skills). This leads to the conclusion that this kind of measurement does not measure what it is supposed to. This only leaves trainer assessed as a potential measurement, but especially this one shows inconsistencies with peer and self evaluation. And having a trainer assess the added value of his or her own actions does not seem right.

This is not a quantitative research. We only used a small sample to test whether the design criteria could remove the potential problems, like inaccuracy, attrition and stage one learning. And we used it on one course only. This may have been wise, as the averages appear to show some kind of learning, the student level reveals that this is mostly due to averaging out strange effects on student level. Tested on bigger numbers of students, this could have remained hidden.

The design used a relative rude scaling of the answer options, which allows students to quickly assess themselves and others. On the other hand it does not allow for small changes in confidence level to be detected. One can wonder if a student, peer or trainer would indeed give more reliable answers in a more detailed scale. Given the results, further research in this area seems pointless.

Our premise that comparing perceived ability would solve over- and underestimation cannot be proven.

8. Conclusions and suggestions

Our research set out to define criteria - based on literature - for using SALG as a method of measuring added value. The test revealed no clues that a design based on those criteria could be used as a method of measuring learning gains, not for use as a self assessment, peer assessment or trainer assessment of learning gains.

Our results supports earlier an earlier statement [23] that using self evaluation does not lead to results that can be trusted, with the addition that we also did not find any clues that a variant of 360 degrees assessment could provide trusted results.

This results underlines that 'Increase knowledge is relatively easy to measure /…./ we can measure attitudes with a paper-and-pencil test /… / [for skills] a performance test is necessary' [26]. Claiming teaching or learning effects using SALG in any form, even using 360 degrees feedback, does not appear to be valid. Not in the field of project management, but most probably in any field.

It would be interesting to disprove our findings. We do suggest that a better track for researching added value is the design of easy to administer but valid assessments of real ability. Further research on more easy to assess abilities could support our findings as we will try in the third test.

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Real-world project management training for Small, Medium and Micro Enterprises (SMME) sustainability

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Abstract

South Africa is one of the countries with the largest disparity in wealth and standard of living in the world. This paper calls for an undertaking in line with the South African government's framework to empower entrepreneurs and community ownership and to overcome some of their shortcomings. This is also applicable to students who are upcoming Small, Medium and Micro Enterprises entrepreneurs in engineering. Two case studies in project design in the electrical engineering field are discussed to show the perception and psychological thinking of individuals about their performance. These students received formal project management training through a collaboration project between the Cape Peninsula University of Technology and the German based World of Eve and Training Development Consulting. The aim of these sessions was to empower entrepreneurs through formal project management training. This is later to be compared to the performance of electrical contractors and project managers in the real world, who did not receive any project management training.

Keywords: *project management, Small, Medium and Micro Enterprises. Entrepreneurship*

1. Introduction

1.1. Sustainable enterprise and Broad Based Black Economic Empowerment

Broad-based Black Economic Empowerment (BBBEE) was initiated by the South African government to improve the former biased and unfair Black Economic Empowerment (BEE) programme, which was aimed at addressing the legacies of Apartheid. According to Act 53 (2003), Codes of Good Practice for Black Economic Empowerment, there are three enterprise sizes that are scored according to different sets of measurement criteria: Generic Enterprises, Qualifying Small Enterprises and Exempted Micro Enterprises.

Generic Enterprises have a turnover of greater than R35 million. It is estimated that only 4% of South African Enterprises fall into this category. These companies must apply all seven pillars of BBBEE (Code 000-700 of the act). Qualifying Small Enterprises (QES) have a turnover between R5 million and R35 million. They are required to apply code 000-800 to calculate their scorecards. QSE’s can choose the best four of their seven elements, with each element accounting for 25% for their scorecard.

Exempted Micro Enterprises (EMEs) have turnovers of less than R5 million. It is not necessary for EME’s to be rated, but they need to be able to provide reasonable evidence that they are EMEs. For EME’s greater than 50% black owned, they automatically qualify as 110% contributors towards Preferential Procurement.

This means that a newly registered black-owned small business immediately qualifies as 110% contributors towards Preferential Procurement as an EME. These companies normally have fewer overheads than their competitors, giving them the advantage to tender at lower prices. In addition, the 100% scored for black ownership increases their chances of securing a winning tender. While many tenders are awarded to these companies as a result of the aforementioned factors, many lack effective project management skills to ensure the successful completion of awarded contracts.

The minister of trade and industry has published a sector code on black economic empowerment in terms of the BBBEE in Government Gazette 32305 on 5 June 2009. Companies are now invited to have their BBBEE

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Charter rating reflected on the Construction Industry Development Board (CIDB) Register of Contractors if they are in possession of a BBBEE certificate. These certificates are issued by rating agencies accredited by the South African National Accreditation System (SANAS). The BBBEE rating will be automatically removed from the CIDB database after one year and requires updating by the company upon certificate expiry date.

A survey undertaken by management consultants Grant Thornton, and released in June 2009, confirmed that 63% of private businesses finally regard the Black Economic Empowerment (BEE) Compliance or BEE codes of good practice in the workplace important for winning business or tenders, especially from the state – years after the government introduced it. [1]. Johan du Toit, MD of SANAS-accredited BEE Rating Solutions, reports that the introduction of the accreditation system has resulted in a steep rise in the demand for verification certificates from the small and medium-sized enterprise market.

BEE Verification Agency CEO Willem Mostert stated that in certain industries, such as construction where the state is most likely the issuer of tenders, government departments place strong emphasis on certification of prospective tenderers. Although there are seven aspects to the code, emphasis is placed on ownership and management only – the neglected categories include: employment equity, skills development, preferential procurement, enterprise development and socio-economic development. The South African Minister of Trade and Industry, Rob Davies, announced that only certificates issued by accredited BEE verification agencies would be valid for tendering purposes as from February 2010.

At the moment government tender adjudicators award additional scores to companies that are black female-owned or where the owners are disabled. This however, does not mean they these companies have the necessary skills to successfully project manage the contract. Many win tenders because of their BEE status, but many Small, Medium and Micro Enterprises (SMME's) fail to produce due to a lack of skill and experience in the field or within the effective management of the project.

An actual example is one of a small company that won a R5-million tender for a medium-sized electrification contract. After a few weeks the owner was found, alone on site with a spade, busy digging trenches. He did not want to "waste money" by employing additional labouring staff. By that time he was so far behind the project deadline that it was cancelled and re-tendered. Another example is a contractor who could not deliver on a first line maintenance contract because he did not have any vehicles. Another one did not have any cash flow to pay wages with the result that his workers sabotaged the project. The list is endless and is a serious impediment in government's push toward providing basic services to previously disadvantages communities. This emphasises the need for sociological facilitation for sustainable SMME's.

1.2. Collaboration to empower entrepreneurs through formal project management training

The Electrical Engineering and Information Technology departments of CPUT, in collaboration with international partners, World of Eve (WoE) and Training Development Consulting (TDC), both from Germany, recently completed an agreement to amongst others, empower students on various CPUT campuses and close community members, with project management skills.

World of Eve is headed by Ms. Eva Ploder who, amongst others, was contracted with providing support for the ongoing cooperation between Bavaria (Germany) and the Western Cape (South Africa). This collaboration by both the Bavarian government and The Provincial Government of the Western Cape has been running since 2011. In 2012, WoE coordinated the first upcycling design at the "Too Good to Waste" Exhibition at the 2012 Munich Design Week and was subsequently invited to the 2014 World Design Capital event in Cape Town.

Ms. Andrea von Gleichenstein is the director of Training Development Consulting. TDC's main focus is on Project Management, Intercultural Communication, Team work and Soft skills development. Some of the main clients of TDC are the Bavarian Chamber of Commerce, BMW, GIZ etc.

The two authors, Dr. Wilfred Fritz and Deon Kallis of the Electrical Engineering Department are heading the Cape Peninsula University of Technology Team in the collaboration. The two realized that a number of students start their own entrepreneurial business in electrical engineering and that effective project management should not be a mere theoretical concept treated in isolation of the real world of business.

An MoA with regard to the establishment of a collaborative relationship in the field of project management and design between CPUT and WoE & TDC (Germany) has been signed by the CPUT Deputy Vice Chancellor:

Dr Chris Nhlapo and the German partners. Figure 1 is a photograph taken on the day of the signing of the MoA, with the following roleplayers:

Dr Chris Nhlapo (Deputy Vice Chancellor: CPUT),
Ben Groenewald (HoD: Electrical Engineering Department),
Dr Wilfred Fritz (Electrical Engineering Department)
Deon Kallis (Electrical Engineering Department),
Wendal Koopman (Information Technology Department),
Eva Ploder (World of Eve Germany),
Anni Friessnegg (WoE South Africa) and
Andrea von Gleichenstein (Training Development Consulting).

Figure 1. South African and German role players at the signing of the collaboration agreement.

2. First Case Study: Community member's performance without receiving any formal project management training

The above-mentioned entrepreneurial contractor's performance was monitored over a period of a year and will be compared to that of students who received formal project management training. These were assigned electrical contractors and "project managers", who did not receive any project management training.

A tender for a project to install 1200 prepaid electrical meters and ready boards (compact distribution boards) in an informal settlement in Franschhoek, Western Cape was awarded to an electrical engineering company. It was compulsory to use labour from the local community. The electrical engineering company that won the tender subsequently subcontracted the installation part (labour only) to a local subcontractor.

Each of these households were issued with a 20A supply since the informal settlement was situated in a low income group. A split-type prepaid meter (where the prepaid meter is fitted in an enclosure and mounted on an

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outside streetlight pole, and linked to a keypad fitted next to the ready board inside the dwelling) was used in project. This arrangement is an attempt to reduce meter tampering inside the dwelling.

Within the first few days of the commencement of the project the authors questioned whether the sub contractor and his project manager had training or experience on "how to manage staff" or "how to do proper budgeting and cost estimation in the planning process" in electrical engineering projects. Some of the shortcomings varied from arriving on site without any tools to incurring huge daily overheads.

2.1. Breakeven Analysis and Learning Curves

The starting point of financial planning should be simple breakeven analysis. If a contractor is paid a price *P* per installation and pays a fixed cost *F* and a variable cost *V*, then for *n* installations, the net revenue *R* received is

$$R = nM - F \qquad (2)$$

Where the contribution margin *M* is the difference between the unit price and the variable cost (M = P – V). Breakeven occurs at installation n_b where the net revenue $R = 0$. Equation 2 at breakeven now becomes

$$F = M\, n_b \qquad (3)$$

So the number of installations to be made to reach breakeven is

$$n_b = F / M$$

Rearranging (3) and (2) results in the total revenue *R* in terms of the contribution margin breakeven point

$$R = (n- n_b)M$$

In Figure 2, the breakeven analysis is illustrated by a plot of daily revenue versus volume (number of installations). In this example it can be clearly seen that at a fixed cost of R325 the breakeven point (n_b) is at 3 installations. If 15 installations are completed, the daily profit should be approximately R1 000.

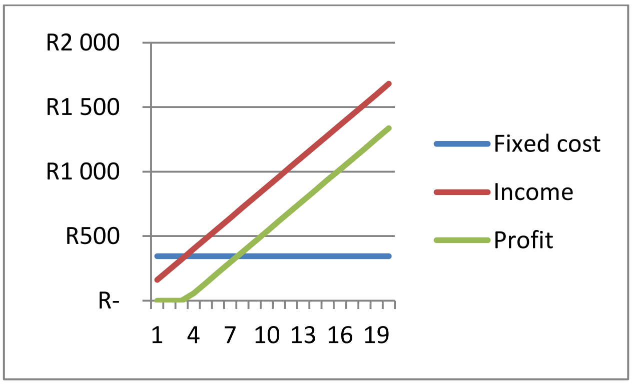

Figure 2. Plot of revenue versus installations

However, this linear model can only be used for budgeting if the installations are done by an experience team, and where all the installations times are completed in the same time. Measures of uncertainty of the duration of an activity is given by the variance,

$$\sigma^2 = ((b-a)/6)^2$$

Where

σ = standard deviation (one sixth of the beta range)
$=(b-a)/6$
a = optimistic time estimate
b = pessimistic time estimate [3].

Consider a project that requires 10 installations to be done on day one. If an installation uses 1 hour of direct labour and for a labour rate of R20 per hour, and if benefits equal 28 percent of the wage rate, the estimated labour cost on day one would be

1.28(R20/hr)(10units)(1hr/unit) = R256.

This would be an underestimate because more time is used early in the installation period since human performance normally improves when a task is repeated. Each time the output doubles, the worker hours per unit decrease to a fixed percentage of their previous value. This percentage is called the learning rate.

In the example above, if it requires 1 hour to accomplish one task the first time it is attempted and only 0.8 hours the second time, the learning rate is 80%.

The time it takes to produce one unit of output (one installation etc.) is given by this well known formula

$$T_n = T_1 n^r \qquad (4)$$

Where

T_n=the time required for the n[th] unit of output
T_1= the time for the initial unit of input
n = the total number of units to be produced
r = $\log_e$ learning rate / $\log_e 2$

The total time required to produce all units on a production run of size N is,

$$T = T_1 \sum_{n=1}^{N} n^r$$

[3].

We can now calculate the time it would have taken for the initial unit:

$r = \ln 0.8 / \ln 2 = -0.322$

After 20 units equation (4) becomes

$1 = T_1(20)^{-0.322}$

And the time taken for the first unit becomes

$T_1 = 2.624\ hr$

Therefore the estimator needs to budget the first unit at the same rate, but over a longer period, viz. 2.64 hrs and not 1hr.

3. Second Case Study: Students receiving formal project management training

Two interactive project management and teamwork workshops were held and used as case studies in project design and installation in the electrical engineering field. Students were tasked with a similar project than that of entrepreneurs in the community, as in case study 1.

The above-mentioned collaboration project is multidisciplinary involving 71 students (60 x electrical, 10 x information technology and 1 x mechanical). This has been integrated into the student's formal coursework or Work Integrated Learning (WIL) requirements.

An initiation meeting and Project management & Teamwork training workshop was presented by TDC to 60 Projects II EE diploma students at the CPUT Bellville campus at the beginning of 2015. On the respective days, the project objectives were clarified and students were also tasked with group assignments related to their Projects II course work.

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Interactive teamwork activities were carried out and are depicted in Figure 4. The main project objectives were:

- To empower local entrepreneurs and
- To conduct training and workshops on relevant topics in project management and multidisciplinary teamwork

This training workshops form part of the formal coursework of the Projects II and Project Design III in the Electrical Engineering programme. The IT department will manage the software development as a sub-component of Project 4 of the software supervisory system, by engaging two BTech IT students and the full-time deployment of 8 IT final year students within the Simulated Industry Environment programme. All the students of the above-mentioned 4 subjects are to be present in the follow-up project management and multidisciplinary teamwork training workshops.

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Figure 3: Project management & Teamwork training workshop presented by Andrea von Gleichenstein of TDC

Figure 4: Interactive teamwork activities being carried out by students during the first workshop

4. Findings

The following was uncovered about the perception and psychological thinking of individuals in the case study about their performances: After the first workshop an evaluation session revealed that most students thought that they have excellent project management skills. However, a contrary result was highlighted during the interactive sessions. After students were formally introduced to project management skills such as SMART objectives (Specific, Measureable, Achievable, Realistic and Timely), teamwork and coordination plans, the majority of students realised their own shortfalls in this area. They are now applying these newly acquired skills in their onsite project design and construction. The evaluation survey revealed that all students claimed the training was beneficial towards their project.

The sub-contractor in the first case study did not have funds for capital expenditure, to acquire proper installation and safety equipment and therefore expected an advance in funds. This forecasted that he is heading for disaster. All projects are unique and their budgets are based on forecasts of resource usage and the associated costs. Therefore, estimating the cost for any project involves risk. [3]. Risks are significant with many challenges in project management but at the end of the day with proper budgeting and if the project is successful it is tremendously rewarding. Due to the mistakes and misperceptions about budgeting made in Case study 1, the following was addressed with the students in case study 2: Money is the life blood of business and should be properly spent either as capital expenditure or operating expenditure. [4].

An additional research question that was highlighted was whether the lack of understanding of basic mathematical literacy plays a role in the perception and psychological thinking of individuals regarding budgeting. Schools rather opt to offer maths literacy instaed of pure maths. Maths literacy is a subject that is a dumbed-down version of pure maths. Universities do not recognise maths literacy. What worsens the situation is the fact that maths was scrapped in more than 300 South African schools in 2014 [5]. Since 2008, secondary school leavers needed to obtain a minimum of 40% in three core subjects and 30% in three others in order to pass the National Senior Certificate in South Africa. In 2009, 43% of students dropped out before they reached their final year of secondary school. According to the Department of Basic Education, of those writing the final exams, 49% have opted for the subject mathematics literacy to capitalise on its practical orientation and ease of successful completion as opposed to the traditional mathematics subject. However, only 46% who wrote the

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subject mathematics in 2008 passed. [6]. This was a huge increase on the previous year and led to doubts over whether it was pitched at the right level and whether those who enter the business and project management world are able to do straightforward calculations to find breakeven points for estimates, budgets, costing etc. Some even question whether the subjects, mathematics or mathematics literacy is needed for basic education, where it will not be used by learners progressing to higher education where mathematics is not in the curriculum. It becomes even more worrying, since the 2009 national matric pass rate dropped by 2% compared to that of the previous year [7]. In the 2014 matric examination, more than 280 000 pupils wrote maths literacy and 87% passed and about half the amount of students (143 000) wrote pure maths, of whom a mere 60% passed [5]. This is a huge increase to the 2008 pass rate of 49% and 46% respectively. This increase is questionable since the *Mail & Gaurdian* ascertained that maths is a subject largely accepted as a critical component in addressing the skills shortage in the country. Some schools do not have the necessary teachers and deliberately remove maths and offer only the much easier maths literacy in an effort to increase their overall matric results [5].

5. Conclusion

A number of good policy initiatives have been promulgated and implemented by the government of South Africa in attempts to improve the living conditions of the majority of its citizens and to address the inequalities of our society. These attempts are however, hampered by a lack of skills, particularly those related to project management, of many small enterprises that are awarded governmental and similar engineering contracts. We have attempted to convey these skills within the formal learning context and through application of a real-world engineering problem. Since there is a severe lack of sociological facilitation by government for sustainable enterprises, the next step would be to empower entrepreneurs in communities or small companies with proper training or mentoring. This training would also be addressing the skills shortage in the country.

6. Acknowledgements

The authors wish to thank Andrea von Gleichenstein of Training Development Consulting and Eva Ploder of World of Eve for their enthusiasm and contribution towards their collaboration with the CPUT project management in Renewable Energy project. The students are looking forward to the follow up TDC project management training workshops and interaction with entrepreneurs in communities.

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Presenter

The paper will be presented by Dr. Wilfred Fritz.

The Attributes of a Global Engineer: Purpose, Process, and Findings

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Abstract

For the past several years, the American Society for Engineering Education's Corporate Member Council, reflecting the voice of industry, developed a series of attributes representing the desired competencies needed by engineers in order to effectively live and work in a global context. A global online survey was launched to validate the performance and proficiency levels of each attribute, and a series of global focus groups in every major region of the world have been held for the purpose of clarifying and refining the attributes. In 2015, the Attributes of a Global Engineer Project formally concludes its work, having benefitted from prolonged engagement with and input from globally-representative stakeholder groups of academicians and industry partners. This paper will describe the process to develop attributes of a global engineer; present a summary of key results; discuss how attribute outcomes can assessed in engineering education globally; and provide recommendations for a variety of stakeholders, with particular emphasis on lessons learned from the multi-year Project.

Keywords: *Internationalization, Curriculum Development, Engineering Workforce*

1. Introduction and Context

The American Society for Engineering Education (ASEE) Board of Directors established the Corporate Member Council (CMC) to convey the ideas and views of corporations to ASEE. With over 120 corporate and non-academic institutional members, the CMC's mission is to foster, encourage, and cultivate the dialogue between industry and engineering educators. The CMC has several Special Interest Groups (SIGs), which exist to share information and advance key priorities of the CMC. The International Engineering Education SIG is the CMC sponsor of the Attributes of a Global Engineer Project. The Attributes of a Global Engineer Project grew out of an expressed need by CMC members to identify and validate specific knowledge, skills, abilities, and perspectives that would be required of an engineer living and working in an increasingly global context. Specifically, the goal was to refine a list of attributes that would be applicable to engineers regardless of specialty, location, or background. The Attributes of a Global Engineer Project's principal goal is to "Enhance the employability of engineering graduates and increase the international competitiveness of ASEE's corporate members, so that engineers can effectively live, work, and perform anywhere in the world." (Diane Matt, Chair ASEE-CMC, 2014)

2. Initial Attribute Development and Refinement

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The process of initially developing the Attributes of a Global Engineer began in 2008, led by the International Engineering Education Special Interest Group (SIG), and involved CMC members developing a list of competencies derived from representative job descriptions, literature reviews, and other reports. This initial list was consolidated through a series of SIG meetings and events throughout 2008 and 2009. At the ASEE Annual Conference in 2010, SIG stakeholders attempted to translate the attributes into specific competencies that could be identified by levels of importance and proficiency at certain intervals of an individual's education and professional development. The initial list totaled forty-eight; however, through in-person meetings at the Conference, and through bi-weekly telephone conference calls and other electronic communication, the list was ultimately synthesized and consolidated. After further review and validation from CMC members, a total of twenty attributes of a global engineer emerged. These are:

1. Demonstrates an understanding of engineering, science, and mathematics fundamentals
2. Demonstrates an understanding of political, social, and economic perspectives
3. Demonstrates an understanding of information technology, digital competency, and information literacy
4. Demonstrates an understanding of stages/phases of product lifecycle (design, prototyping, testing, production, distribution channels, supplier management, etc.)
5. Demonstrates an understanding of project planning, management, and the impacts of projects on various stakeholder groups (project team members, project sponsor, project client, end-users, etc.)
6. Demonstrates an understanding of the ethical and business norms and applies norms effectively in a given context (organization, industry, country, etc.)
7. Communicates effectively in a variety of different ways, methods, and media (written, verbal/oral, graphic, listening, electronically, etc.)
8. Communicates effectively to both technical and non-technical audiences
9. Possesses an international/global perspective
10. Possesses fluency in at least two languages
11. Possesses the ability to think both critically and creatively
12. Possesses the ability to think both individually and cooperatively
13. Functions effectively on a team (understands team goals, contributes effectively to team work, supports team decisions, respects team members, etc.)
14. Maintains a positive self-image and possesses positive self-confidence
15. Maintains a high-level of professional competence
16. Embraces a commitment to quality principles/standards and continuous improvement
17. Embraces an interdisciplinary/multidisciplinary perspective
18. Applies personal and professional judgment in effectively making decisions and managing risks
19. Mentors or helps others accomplish goals/tasks
20. Shows initiative and demonstrates a willingness to learn

3. Survey Research on the Attributes of a Global Engineer

After completing a stakeholder-driven process to develop the attributes of a global engineer, SIG members sought to validate the list of attributes with stakeholders beyond the CMC. Given the global dimensions and emphasis of the attributes, SIG members were desirous of a mechanism to receive widespread feedback from a truly global audience of engineering-oriented stakeholders. The CMC partnered with the International Federation of Engineering Education Societies (IFEES) to accomplish the goal of widespread global stakeholder input and validation. IFEES consists of nearly 50 member organizations, representing engineering education associations and corporations from around the globe. Dr. Hans Hoyer, who serves Secretary General of IFEES, facilitated connections between the SIG leading the attributes of a global engineer project and IFEES stakeholders around the globe. This purpose was two-fold: (1) to garner assistance in translating the survey into multiple languages (including validation of the survey once translated); and (2) to secure assistance in marketing the survey opportunity to IFEES stakeholders worldwide.

From July-September 2010, the survey was translated from English to the following languages: Chinese (Simplified and Traditional), French, German, Italian, Japanese, Korean, Polish, Portuguese, Russian, Spanish and Turkish. Translators also assisted in validating the survey with a small representative audience of likely survey responses. This was done to ensure that the intent behind attribute meanings was preserved across all translations. Translators were asked to make appropriate substitutions to words or phrases in the translated context to accomplish this goal. Using SurveyMonkey as the data collection platform, the survey was launched in October 2010; a work-in-progress paper was presented at ASEE’s 2011 Conference in Vancouver; additional responses were received by and the survey was closed for additional responses in September 2011.

The survey yielded 1,027 usable case respondents reflecting the following demographic profile:

- 70% English; 30% non-English; responses were received from all languages except French
- 80% Male; 20% Female
- 50% between ages of 40-60; balance over other age ranges
- 46% Academicians; 40% Practitioners; 10% Students; balance preferred not to answer
- Aerospace (17%); Computer Science (13%); and Electrical/Computer (13%) are largest Engineering Discipline response categories
- 64% reported having graduate-level Engineering degree

Data analyses revealed the following attributes were most important and proficient overall:

1. Communicates effectively in a variety of different ways, methods, and media
2. Possesses the ability to think both critically and creatively
3. Shows initiative and demonstrates a willingness to learn
4. Functions effectively on a team
5. Possesses the ability to think both individually and cooperatively
6. Demonstrates an understanding of engineering, science, and mathematics fundamentals
7. Demonstrates an understanding of information technology, digital competency, and information literacy
8. Maintains a positive self-image and possesses positive self-confidence

When analyzing above attributes at each stage of an engineer’s development (upon completion of high school/secondary school; university; early-career professional), the importance and proficiency levels of each attribute varied, as follows:

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The most important/proficient attributes for the *secondary school graduate* are:

1. Demonstrates an understanding of engineering, science, and mathematics fundamentals
2. Maintains a positive self-image and possesses positive self- confidence

For individuals at this stage, the need to have sound preparation in the disciplinary fundamentals is needed for successful transition to and success in university-level engineering education programs. Furthermore, student retention and success in most first-year university engineering curricula requires resiliency and the positive self-image/self-confidence.

The most important/proficient attributes for the *university/post-secondary graduate* are:

1. Demonstrates an understanding of engineering, science, and mathematics fundamentals
2. Demonstrates an understanding of information technology, digital competency, and information literacy.

For individuals at this stage, the need to have master of the disciplinary fundamentals upon departure from university-level engineering programs is most important. Furthermore, the ability to be proficient in and up-to-date with the tools and technology of the field are also needed.

The most important/proficient attributes for the early-career engineering professional are:

1. Functions effectively on a team
2. Possesses the ability to think both individually and cooperatively

For individuals at this stage, the need to work as part of an engineering-oriented team are most important, as is the ability to make both individual and collective contributions to engineering-oriented work.

After analyzing, summarizing, and disseminating results from the survey, SIG members felt it was necessary to conduct focus groups and workshops related to the attributes. The next section highlights the process and findings from those endeavors. In order to garner additional input into the Attributes of a Global Engineer, a series of focus groups and workshops were conducted in several venues. From 2012-2015, events were held at engineering-related conferences, symposia, and workshops in the United States, Finland, Belgium, Colombia, Argentina, Japan, U.K., Spain, U.A.E., and India. In all but one event, the principal attendees were university-level engineering educators or industry partners. The October 2013, San Antonio, Texas, event provided an opportunity for K-12 and community/technical college stakeholders to have input into the Project. Each event was structured as both a *focus group* (to seek stakeholder input) and a *workshop* (to permit the dissemination of findings and encourage integration of attributes into the engineering curriculum).

During the focus group portion, highlights from the survey findings were shared and discussed, and participants had an opportunity to provide reactions or contribute additional information related to the attributes. A summary of the attributes the collective stakeholders from all events felt were needed for engineers to be successful in the global context included the following:

- ultural sensitivity

- Tolerance to other people and perspectives
- Open-minded and ability to adapt
- Ability to behave ethically across cultures
- Social responsibility
- Research and analytical thinking
- Problem-solving and improvement capabilities
- Entrepreneurship

Stakeholders at each event were also queried as to the best uses of the attributes, which they identified as:

- Teaching and learning processes and student preparation
- Business/industry involvement as vocal advocate for attributes
- Linkages to other initiatives

Finally, while focus group and workshop participants uniformly expressed appreciation for the Attributes of a Global Engineer Project, there was widespread agreement that a framework of twenty attributes seemed daunting to remember, explain, or champion. Thus, stakeholders provided useful guidance on helping SIG members develop a revised framework.

4.Revised Framework for the Attributes of a Global Engineer

To facilitate greater utility of explaining the purpose of the Attributes of a Global Engineer, and to encourage their integration into the engineering curriculum, SIG members have revised the framework based on feedback from focus group and workshop participants. The new framework retains the twenty attributes, yet organizes them more effectively around five broad categories needed for global engineering effectiveness: Technical; Professional; Personal; Interpersonal; and Cross-cultural. Descriptions of each category and corresponding attributes are listed below:

Technical: Engineering-related knowledge, skills, and abilities needed for success

- Demonstrates an understanding of engineering, science, and mathematics fundamentals
- Demonstrates an understanding of information technology, digital competency, and information literacy
- Demonstrates an understanding of stages/phases of product lifecycle (design, prototyping, testing, production, distribution channels, supplier management, etc.)
- Demonstrates an understanding of project planning, management, and the impacts of projects on various stakeholder groups (project team members, project sponsor, project client, end-users, etc.)

Professional: Workplace related competencies for global performance

- Communicates effectively in a variety of different ways, methods, and media (written, verbal/oral, graphic, listening, electronically, etc.)
- Communicates effectively to both technical and non-technical audiences
- Maintains a high-level of professional competence
- Embraces a commitment to quality principles/standards and continuous improvement

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- Applies personal and professional judgment in effectively making decisions and managing risks

Personal: Individual characteristics needed for global flexibility
- Possesses the ability to think both critically and creatively
- Possesses the ability to think both individually and cooperatively
- Maintains a positive self-image and possesses positive self-confidence
- Shows initiative and demonstrates a willingness to learn

Interpersonal: Skills and perspectives to work on interdependent global teams
- Functions effectively on a team (understands team goals, contributes effectively to team work, supports team decisions, respects team members, etc.)
- Mentors or helps others accomplish goals/tasks

Cross-cultural: Society and cultural understanding to embrace diverse viewpoints
- Demonstrates an understanding of political, social, and economic perspectives
- Demonstrates an understanding of the ethical and business norms and applies norms effectively in a given context (organization, industry, country, etc.)
- Possesses an international/global perspective
- Possesses fluency in at least two languages
- Embraces an interdisciplinary/multidisciplinary perspective

Future dissemination concerning the Attributes of a Global Engineer Project will use the revised framework as the means of organizing and communicating the attributes.

5.Conclusion

The Attributes of a Global Engineer Project has enjoyed several strengths, challenges, and opportunities. *Strengths* include corporate voices reflected in origin and concept development; mixed method approach for attribute development and refinement; and prolonged engagement with global stakeholders. *Challenges* include the large number of attributes identified; competing and co-existing “outcomes” frameworks exist; and engineering curricular tightness, which makes additive educational work impractical. *Opportunities* include the ability to offer corporate perspectives on related initiatives; integrating the attributes with curricular and other efforts possible; and adaptation to local contexts, versus superimposing the attributes on others. The SIG members look forward to continued evolution, dissemination, and improvement of the Attributes of a Global Engineer Project, and to seeing this effort scale and sustain over time.

Robotics

ICEE 2015

Global Collaborative Senior Project: Engineering Design of Robot Aesthetics

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Abstract

This paper presents a show case on aesthetic robot design coupled with technical function constraints and engineering performance analysis method. A global team of engineering students from US and China worked together to improve the robot aesthetic design as their capstone design project, closely working with the industrial sponsor. First a project goal is determined based on robot aesthetic analysis and measures defined. Decision matrices are used to evaluate the aesthetic satisfaction in both component and assembly levels of the design while the scores are assigned subjectively through panel discussion. 3D printing technique is used to get the physical models for rapid verification of the design and to facilitate the design evolution. Examples are given for robot component design as well as the over evaluation of the robot aesthetics. Cultural difference and project coordination is also discussed.

Keywords: *Robot, Aesthetic Design, Senior Project, Globalization.*

1. Introduction

Robots have been developed with various functions, playing important roles in different industries and even in our daily life. To meet a popular need, low-cost and attractive robots are much desired in market. The first electronic autonomous robots with complex behaviour were created in 1948[1]. Over the half-century development since then, technologies used in robot operation and application are very comprehensive and systematic. Today with a variety of robots in high quality, it is hard to differentiate robots only by their functional value, while robot aesthetic design plays a vital role in the market competition. However, there is not a systematic way to design and evaluate the aesthetic aspect of robots[2]. In this paper, an engineering analysis method is introduced to evaluate the aesthetic robot design and clarify the advantages it brings.

In summer 2014, a team of undergraduate students from University of Notre Dame, South Bend, IL came to China to do their senior projects with students selected from Tsinghua University, Beijing China, in mixed teams and work on real world projects sponsored by global companies with China operations. The students went through a very comprehensive project process to learn and practice doing real projects in a multi-cultural

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background[3,4]. The project included a preparation stage before the project time in China. The students worked on team building through communication with project partners, sponsors, and advisors; background study to understand the company and the problem; technical literature review to prepare knowledge and tools to be used in projects; problem definition and project planning with objectives and tasks laid out; and projection of expected outcomes from the projects.

The program has been operated for ten years. In 2014, one of the projects is to study on robot aesthetic design for education market focused on the young people with a combination of function and attraction requirements. The project was sponsored by ArcBotics, a company founded by a former student of Worcester Polytechnic Institute, Worcester, MA, who participated the program a few years ago.

Technical functions and aesthetic attractiveness are coupled together. How to represent the robot aesthetic requirement and performance in a logic way is the first challenge. Then how to rapidly generate and evaluate the aesthetic design of robots with function requirements as constraints in design iteration is also a challenge. In this study, a panel evaluation based scoring system was used to evaluate the design, with the goal to enhance customers' satisfaction of the product. Sketching, CAD modelling, and 3D printing were the techniques used in the study to facilitate the design evolution. Within a short project time, an initial design was analysed and improved to demonstrate the effectiveness of combining engineering design and aesthetic evaluation in robot design.

2. Robot Aesthetics

It is much desirable, particularly in education domain, to make the interesting world of robotics more accessible and sociable for students and robot enthusiasts. Each of these criteria has a twofold meaning: the sociable aspect must be both cute and cool to the consumer, while accessibility requires the hardware to be affordable and the parts and movements to be software hackable. Cute represents the endearing appearance, behaviours, and emotional effect, while cool can be described based on young and hip/fashion impression[5].

A humanoid robot may strengthen the interaction between human and robots. There still remains a question about how close the humanoid robots should look like human. A famous theory about the aesthetics of humanoid robots is called the uncanny valley which tells us that the familiarity of a robot to human may change along with the similarity of a robot to human. In the relation curve, there exists a valley right before the 100% human likeness, which means that a robot close to human in appearance may look like a corpse or zombie[6]. But in the meantime, another essay indicates that if an object resembles a person too closely, a mismatch may be expected between perceptions of "object" and "person", which may cause disorientation and result in the "uncanny" [7].

From artistic aspect of robot design, one challenge is to determine the design criteria, from experience/feeling type of personal preference to a systematic way which can be justified. For an interactive robot, it does not need to imitate exactly the same human motions and gestures. Good social interaction with human plays a more important role than the accuracy in applications in order to attract customers. With some tolerance in the

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range of motions, the robot can perform better and provide its owner with psychological enrichment[8]. Besides, aesthetic interactions of robot like an innocent play make it look sociable, even if it expresses any negative emotion or fails to imitate human actions perfectly[9]. To enhance the sociality of robots to human and also avoid the creepy appearance in the vague area of humanoid robotic aesthetics, the child-like and cartoon-featured robot may be a better design choice.

A design pattern theory has been widely used in architecture design. The patterns are regarded as design guideline for building designs to help architects in generating new designs[10]. Similar patterns can be referred to in the field of human-robot interaction to enhance the sociality of humanoid robots, such as the initial introduction and didactic communication for robots to become good friends with humans. But such patterns are not fundamental, because even with the social motions guided by the patterns, robots may still be unsocial with a creepy appearance. Therefore it would be much beneficial to come up with certain measures (criteria) to evaluate the design patterns to compare different robot aesthetic designs.

By looking into the robotic aesthetics, in this study, typical representing measures are defined to include the following: 1) Gendered vs. Neutral, 2) Skeletal vs. Covered, 3) Action Figure vs. Doll, 4) Social, 5) Polished, and 6) Humanoid Movement. These are distributed in face, arms, torso, and legs, as shown in Figure 1.

Gendered—Neutral	**Skeletal—Covered**	**Action Figure—Doll**	**Social**	**Polished**	**Humanoid Movement**

Body Part
Face
Arms
Torso
Legs

Figure 1. Robot aesthetic measures

3. General Technical Robot-design Procedure

The typical engineering approach to design a robot is using quantized criteria building a robot like any other machines to reach specific measurable objectives. For instance, Atlas by Boston Dynamics is a high-mobility humanoid robot designed to negotiate outdoor, rough terrain[11]. The functions may include the capability of walking bipedally leaving the upper limbs free to lift, carry, and manipulate the environment.

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For a lone time, the development of humanoid robot has been mainly focused on the technical perspective. A lot of research has been done on the robot kinematics, fascinating mechanism, flexible operational capabilities, error robustness and other technical challenges. However there is not a general procedure and methodology to design the aesthetic aspect of robots with enjoyable appearance and actions, low cost, easy to tweak and comfortable to play with. Researchers have yet to plumb the depth of the "non-technical" issue, as many customers desire. The performance should also be measured for comparisons in design stage. The purpose of this study is to explore a systematic way to design a robot which possesses a nice-looking appearance and user-friendly social interactions, while with adequate capabilities as a condition.

The typical robot design procedure can be summarized like other mechanical design as[13]: 1) Need identification to determine the design specifications; 2) Brainstorming and conceptual design; 3) Detail design and performance analysis; 4) Prototyping and testing; and 5) Finalization of the design. Certainly many steps of evaluation/feedback may be involved in the design process. Similarly these steps could be applied to the aesthetic design of robots.

4. Technical Constraints in Robot Aesthetics Design

Although robot aesthetics is designed and evaluated subjectively, we tempt to use an “engineering way” to do it based on reasoning and quantitative evaluation. Our goal is to design a small-scale robot which aims to be accepted by people in all ages. The appearance should be human-robot interactive, or in other words, social. Sociality is a characteristics to describe an object by human tendency to stay/play with. A study was carried out to test the sociality of humanoid robot and showed that people could easily understand the facial expressions, gestures and actions of humanoid robots.

The technical specifications of the humanoid robot to be designed include 24 degrees of freedom, with NiMH Battery, 24 5v Servos, & a Raspberry Pi Controller, as shown on the left side in Figure 2 and an initial design was conducted on the right side, with consideration but without quantitative evaluation of the aesthetics.

Figure 2. Skeleton model of robot’s 24 DOF

The physical design had to retain hardware accessibility. This means that the robot should be low-cost and easy for the user to modify, accomplished by minimizing the number of parts and designing all parts to be injection mouldable by simple-straight-pull equipment and easy to assemble[14]. Solutions like building connections to be parallel to the part removal were employed to make the robot more manufacturable. Ultimately, this project involves devising solutions like this one while working towards a more accessible and social robot.

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5. Engineering Design of Robot Aesthetics

Since there is not a systematic way of designing robot aesthetics found in literature, a new method was proposed to guide our design and evaluate different iterations of design, which finally led to the new robot within a short time, in our case only 7 weeks.

Steps of this method to design robot are listed below:

- Problem definition for finding out what characteristics or attributes are needed and also what target customers want to see in the robot.
- Goal determination to show basic appearance and functions of the robot through an on-line survey and result analysis.
- Objective setting for more specific definition of the goal and a limited scope of development.
- Methods with a decision matrix applied to determine the design concepts in both overall and component levels and subjective scores through panel discussion.
- Tasks to conduct component design with engineering considerations by generating CAD models and to determine the aesthetic performance of the design through evaluation scoring;
- Criterion selection to regulate the impact of subjective preference in each iteration of design.
- Implementation for design the robot with evaluation and redesign loops where the rapid prototyping of the components and assemblies were used for quick feedback on performance and feasibility verification, through 3D printing; and
- Conclusion to finalize the design and demonstration.

Aesthetic goal. Since the goal is to create a cute, cool, sociable and affordable robots, defining cute and cool is an important to start the project. In the first step, an online survey was conducted by ArcBotics[15]. Besides the background information about the participants, the survey asked what physical characteristics they desired in a commercial humanoid robot. The survey results are summarized below:

- Background information of the survey attendees,
  - Gender (male: female)
  - Education: Mostly bachelor’s degree or higher
  - Income range: large amount of disposable income
  - Interest: Maker/hacker, tech enthusiast, tech professional
- Desired physical characteristics in a humanoid robot
  - Gender (greatest frequency to least): Neutral, Male, Female
  - Enclosure (greatest frequency to least): Skeleton with exterior shell, skeleton, fully enclosed
  - Style: Edgy, Social, and Polished were considered almost equally important, edgy was most popular by a slight margin

Based on the survey analysis, it was determined that the best design would be gender-neutral, while enclosing internal parts as much as possible without restricting movement

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capabilities. While customers wanted a humanoid robot, it was imperative that the new design avoid the uncanny valley, especially in the face and hands—two parts of a humanoid robot (and humans, too) that are key to social interaction.

By using the design matrix and the six robot aesthetics measures, the original design of the humanoid robot is evaluated and scored as shown in Table 1. The scores for each category ranged from 0 to 4, which is such chosen so that when a design contributed most to a category, it would result in a score of 4, while if failed to contribute, it result in a score of 0. After a group discussion particularly on the survey results, a target robot aesthetic design score was determined as the goal as shown in Table 2. It is important to note that the goal score was not the same as the ideal score. It has been constrained by accounting for the limitations of servo location, orientation, and size, as well as the degrees of freedom, the number of parts, and manufacturing cost. Conversely, the goal score did take these considerations into account, so the group prioritized reaching the goal score rather than the ideal score.

Table 1: Analysis of original design (ArcBotics' prototype)

Body Part	Gendered—Neutral	Skeletal—Covered	Action Figure—Doll	Social	Polished	Humanoid Movement	Total
Head	4	4	3	4	3	2	20
Arms	1	1	1	1	1	3	8
Torso	2	4	2	3	3	2	16
Legs	1	0	1	0	2	3	7
Total							51

Table 2: Goal score rubric for the overall robot design

Body Part	Gendered—Neutral	Skeletal—Covered	Action Figure—Doll	Social	Polished	Humanoid Movement	Total
Head	4	4	3	4	4	4	23
Arms	3	4	3	2	4	2	18
Torso	4	4	2	4	4	3	21
Legs	3	4	4	4	4	4	23
Total							85

Sketch Design. After determining the general design guideline, a series of designs were sketched, both for individual parts and for the robot as a whole. Preliminary sketches were used to explore ideas for the robot's appearance as well as to brainstorm features that users would find useful or endearing. A sketch then was created that combined the features and aesthetic principles evident in numerous preliminary sketches. The robot aesthetic design is constrained by and coupled with the technical function design.

Generation of a robot component list. Desirable features were selected after sketches of each body part which were compiled and analysed. Characteristics including

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aesthetics, functionality, and feasibility were considered and discussed, and a list of potential components was created.

The feature list included: a face mask, a battery screen and power button, directional noise detection, a backpack, LED pointers and emotional indicators, a watch-like item, etc. These components were chosen because of their likeness to increase the score of the robot based on the criteria. Considering this list, only a few features were implemented in the final sketch of the goal robot because including all of the components would make the design too cluttered and the robot would not look cohesive and polished.

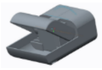
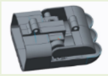
The face mask was included because it provided more area for the LEDs to be placed, which would determine how emotive the robot could be. Having a backpack to house the Raspberry Pi computer essentially saved a lot of room within the torso of the robot as well as being an aesthetically pleasing accessory. This meant that the body could be much thinner and have more room to house servos.

Technical performance consideration. After selecting components, several engineering factors need to be considered prior to the detail design of the components. For example, when sketching each component, compromises between the amount of plastic covering a joint and that joint's range of motion (ROM) were necessary. Such compromises occurred at all joints but to varying extents. For example, the hip required greater ROM in all three DOF than the ankle. Therefore the hip had less plastic around it than the ankle did. The mathematical justification for the inverse relationship between a joint's amount of covering and its ROM is presented in reference[16]. This problem led to a modification of the scoring system. Ultimately, ROM was prioritized over joint covering. As a result, the goal scores for certain parts were almost but not quite achievable, because an improvement of one point in "Humanoid Movement" could easily lead to a loss of multiple points in other categories, namely "Skeleton-Covered," "Social," and "Polished." To deal with this possibility, a modification of two points away from the goal score was made for each part and 5 points away from the goal score for the entire robot.

Detail design and CAD Modelling. Component design includes many cycles of evolution. The design evolution of the robot hand illustrates the iterative design process. As indicated in Table 3, the locations of the robot 24 DOF entailed the absence of a wrist joint; i.e. the hand and forearm would move as one unit, actuated by a servo placed at the elbow joint. Another servo placed in the hand would control grasp.

In the initial sketching phase, two categories of hand actuation were considered. Designs in the first category used a servo to open and close the hand, much like the claw on a crab or lobster. Designs in the second category used various mechanisms, such as four-bar-linkages, rack-and-pinion gearings, and worm drives to achieve more complex grasping motions. Designs in the first aesthetic category consisted of an upper half and a lower half, dubbed a thumb. Designs in the second category consisted of a palm and multiple separate fingers. Upon considering the manufacturing cost and assembly difficulty associated with individual fingers, all designs in the second aesthetic category were dismissed in favour of the first aesthetic category. Designs in the second actuation category were also rejected in favour of a hand that could be opened and closed simply by one servo, thereby simplifying both the assembly process and the relationship between the hand's joint space and actuator space.

Table 3. Hand & thumb evolution

Iteration	Gendered —Neutral	Skeletal—Covered	Action Figure —Doll	Social	Polished	Humanoid Movement	Total
Original	4	1	1	0	1	2	9
	3	2	2	1	1	2	11
	4	3	3	3	3	2	18
	4	3	4	4	3	2	20
Goal	4	3	4	4	4	2	21

In general, function and aesthetics designs are coupled together. In parts where aesthetics were prioritized, improvements generally occurred first in function, while aesthetic improvements took longer to realize. Conversely, in parts where function was prioritized, aesthetic improvements generally preceded functional improvements.

3D printing. Having a physical model in addition to a three-dimensional virtual model is advantageous because it allows for physical manipulation of the part. It also illuminates many faults that are not easily seen in CAD models, i.e. structural flaws or inexact dimensions. A CAD assembly can report the global interference of parts, but this is assuming the parts manufactured are identical to the parts modelled. Given a physical model, the difference can be evaluated between a theoretical CAD model and its tangible counterpart. This allows for a comparison of the interference calculated in Creo and the actual interference of the physical part.

A 3D printer is capable of swift production of a CAD model through a process of additive manufacturing. Within about an hour, the part becomes tangible. The ease of 3D printing and the low cost of ABS plastic make it an effective and affordable addition to the design process. In each iteration, a physical 3D model of each part was printed and assembled for analysis of the ROM per subassembly, aesthetics, and cohesiveness. After each evaluation, corrections were made in the CAD model and printed again for redundancy and further analysis.

Evaluation of the final design. To evaluate all designs, a scoring rubric was used to evaluate the CAD models and physical models. Upon completion of each iteration of the sketch-CAD-3D print process, the robot was evaluated against the goal in Table 2. The result is listed in Table 4. Figure 3 shows the CAD models of the design iterations.

As stated in the introduction, the goal of this project was to design a cool, social and accessible humanoid robot. A quantification of the goal was included above in Table 2. The goal robot had a total score of 85, and as mentioned when taken account of the technical and non-technical constraints, the final solution was achieved as 81, in comparison to the original score of 51 (as listed in Table 1). The final design did not

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correspond perfectly with the original proposed design due to some design constraints met along the way. For example, one DOF was removed from the head (the original proposal called for 25 DOF instead of 24) to maintain covering and manufacturability of the head piece. As design study showed, certain regions such as the face, hands, and feet have a heightened impact on consumer impression of the robot. Therefore the aesthetics of these regions were prioritized while the quality of movement was prioritized at other regions, especially the hips, knees, and ankles. Figure 4 shows the comparison of the final design to the original one.

Table 4: Analysis of final design

Body Part	Gendered—Neutral	Skeletal—Covered	Action Figure —Doll	Social	Polished	Humanoid Movement	Total
Head	4	4	3	4	4	3	22
Arms	3	4	3	3	4	2	19
Torso	3	4	2	4	4	3	20
Legs	3	3	3	3	4	4	20
Total							**81**

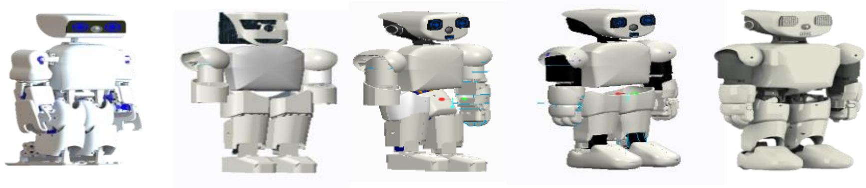

Figure 3. The robot design iterations

6. Summary

This paper focused on the aesthetic aspect of the robot design, although it is coupled with the technical function requirement and engineering constraints. Unlike most of the aesthetic design processes, an engineering design procedure was introduced to the process. First the aesthetic goal is clearly defined with survey and data analysis. Then it is explored to use quantitative evaluation criteria to facilitate the design evolution. Although the evaluation scores used in the design matrices are subjective through panel discussion, the decision process is a reasoning process and can be justified. From the comprehensive design process of the improvement to the initial design, it can be seen most of the engineering design methodologies applied, such as the incorporation with technical constraints and trade-offs in the aesthetic design. The process and final result show the effectiveness of the engineering design method applied to aesthetic design of robots. Hopefully it is also valid and beneficial in other applications.

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A Gentle Introduction to Robotics Software Engineering Education

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Abstract

As robotics becomes increasingly important in technology and therefore in our contemporary society, engineering education needs to increase its offerings related to this new discipline. Since robotics involves topics from several branches of engineering and science, students in this branch need a synthesis of material and techniques from different areas. Our approach is to look at the project lifecycle in robotics software engineering education in the light of experience in existing branches of engineering and to focus on how a synergy can be realized to achieve success in educating students in this new discipline.

Keywords: *software engineering, robot, robotics, software engineering education, mechatronics*

1. Introduction

The general principles for software engineering apply to robotic software engineering as well. We can break down the subject matter into two areas: academic aspects and practical aspects. A subject typically examined under academic aspects is the difference between "software" engineering, in which the products are software, and "hardware" engineering, in which the products are hardware. Differences between these two types of products before, during and after development are emphasized. Robotic software engineering contains a large intersection with robotic hardware engineering due to the high level of dependencies and interactions among robotic components of these two types. The reason for the term "Gentle" in the title is due to a concern that if this multi-disciplinary multi-faceted subject is not introduced in a very well-organized way, the development process can get extremely complicated and the developers may get bogged down easily. Hence to preserve and enhance the enthusiasm the students start with, a well-organized "gentle" presentation by the instructor and well-organized teamwork is vital. For more details on the so-called Team Software Process ^{TM}, see [11]. We also include in the Appendices excerpts from the ACM Curriculum for Robotics courses and IEEE Robotics & Automation publication on Society & Education.

We now discuss the content of practical aspects of these two domains. While there are several approaches to the software development cycle (SDLC) such as Agile and Kanban [19]. In this paper we shall use the classical software Waterfall development cycle [20] which generally consists of the following phases in software product development:

i) **Stakeholder and General Requirement Identification**
In this phase, the students learn about the importance of the so-called "stakeholders" in the project, i.e. groups of individuals or organizations who have a risk and potential benefit from the project. Typically these are the customer and his organization, and even the society in general, the individual users in that organization, the software development company and the individual developers. An output of this phase is a statement of the general requirement(s) for this project.

ii) **Domain Analysis**
Having identified the general requirement for the project, a more detailed analysis of the domain to identify the "actors", their "roles" in the domain and the results of their activities.

iii) **Requirements Analysis**
Detailed analysis of the requirements of the project as accepted by the stakeholders, generally included in a Software Requirements Specification document.

iv) **General Design**

An initial overview of the design for the project based on the information gained from the above phases, typically including overall UML diagrams.

v) **Detailed design**

A more detailed elaboration of the General Design, which can be later used as a guide in the implementation.

vi) **Implementation, testing, evaluation**

The actual code development phase, with an a work plan including a schedule, group responsibilities, an integration plan, a testing plan, evaluation and perhaps additional design and development until the requirements are met to the satisfaction of development management.

vii) **Maintenance and re-engineering**

These phases occur after the product has been installed and put into use. Any problems discovered during use are solved and applied to the product. After a certain amount of usage, if enough new needs are discovered, the product may be re-enginered to resolve the problems and make improvements.

We should note that documentation for each of the above phases should be completed at the end of the phase or shortly thereafter while the ideas and related information are still fresh in developers' minds. These steps may not be followed strictly in this sequence, especially where there multiple groups on the same project. Further, almost always there will be a need to revisit an earlier phase to make some changes. Each such revisit to an earlier phase may require repeated revisits to even earlier phases. There are different formulations of project development phases similar to the one in [21], but in general, most formulations can be accomodated in this structure, called a "Waterfall with Feedback" model, a modification of the classic Waterfall Model. A more detailed treatment of this subject is outside our topic since the project development flow is similar for robotic software engineering. The below figure illustrates this approach, with the addition of feedback from each phase to the prior phase to enable changes in the earlier phase:

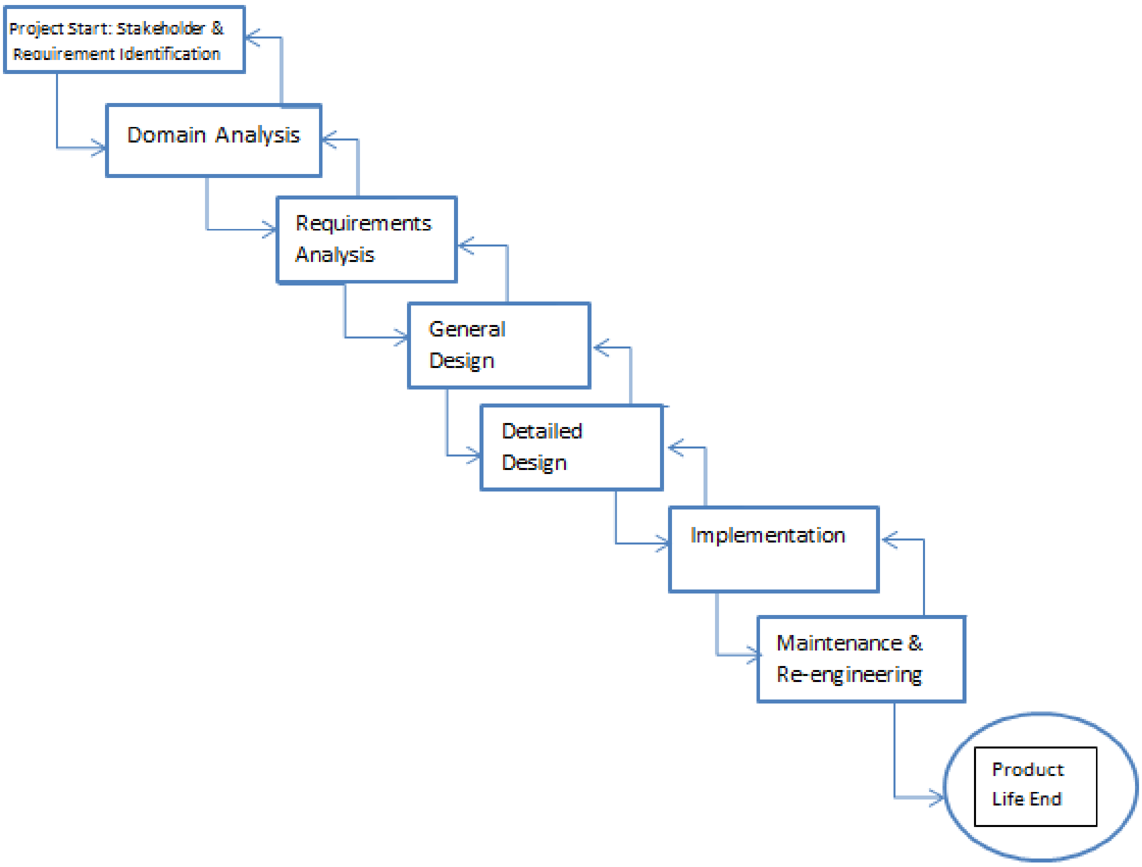

Figure 1. General Product Development Lifecycle

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Some unique aspects of robotic software design and development are as follows:

- Many disciplines are involved (mechanical, electrical, digital electronics, software engineering, human factors, possibly others related to the specific domain)
- Complexity and varieties of robot architecture, functionalities and hardware components
- Each application involves some combination of fields and components mentioned above
- Robotic parts are expensive and evolve quickly

Hence the need for simulation of robotic systems by software has evolved. An overview of some robotics simulation tools is included in [12].

Below is a diagram of software lifecycle after initial development:

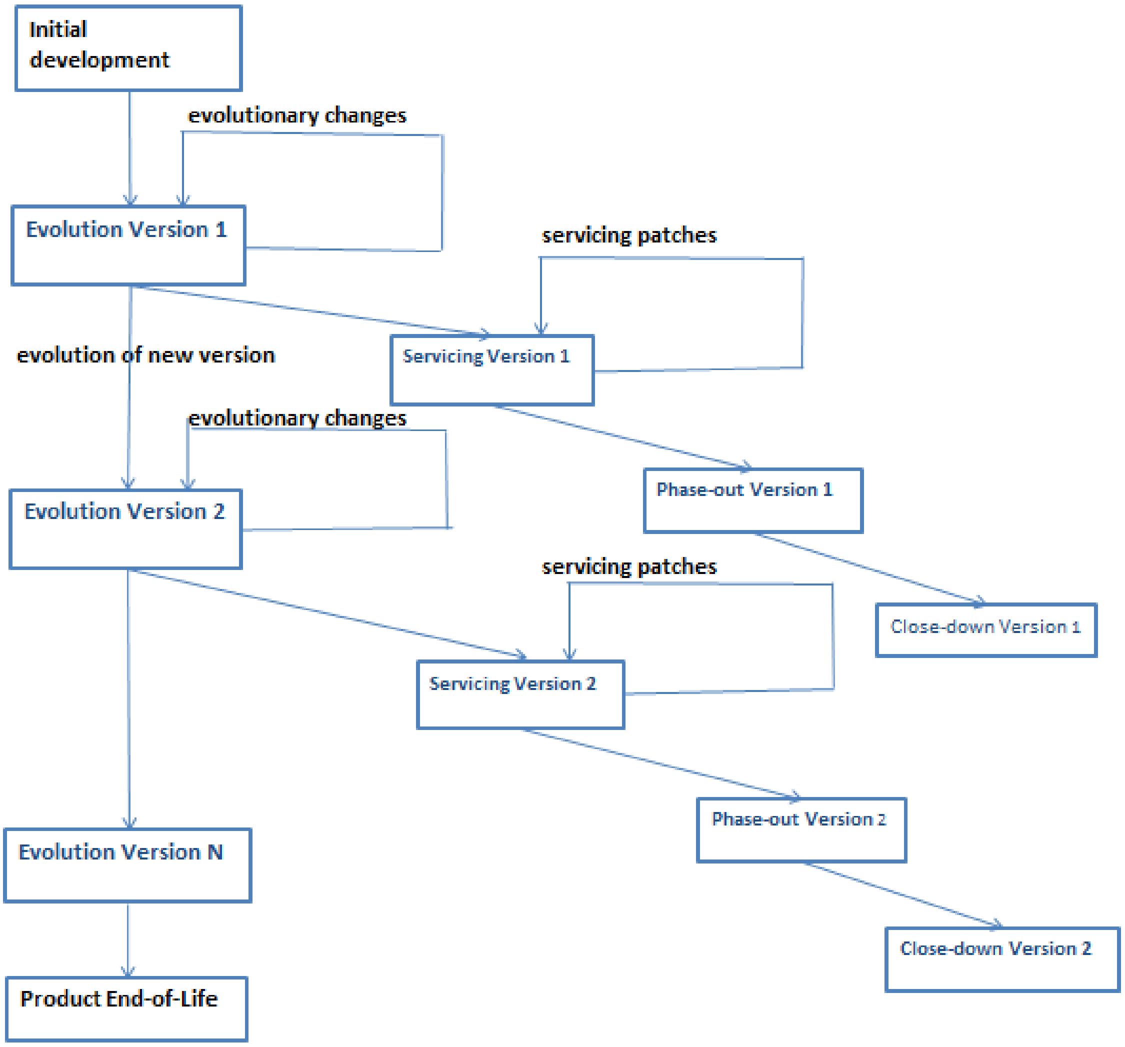

Figure 2. The staged model of software life cycle after release, adapted from [4]

2. Some approaches to robotic software development and robotic analysis

Based on the availability of some simulation models of a robotic components, a number of different approaches to robotic software development has evolved:

- Total software simulation
- Partial simulation and software-augmented hardware
- Software driving both simulator and hardware robot (e.g. assembling parts in a factory)
- No simulation during normal usage

Due to the hybrid nature of robotic architecture including both hardware and software architectures, simulation tool development can be complex. We briefly discuss these alternative approaches below.

2.1. Pure software simulation

This approach can be taken with traditional simulation tools and/or programming languages such as C, C++, Java and Python augmented with a suitable computation package such as Matlab [15], with or without Simulink [16]. In fact, software languages and platforms supporting multi-threading or distributed processing can be used effectively to create the desired simulations. Some simulation techniques are based on pure text output which can be analyzed by a post-processor to make inquiries into the events that took place during the simulation. However, often graphic displays are an important part of a simulation package. If 2D or 3D graphics are required, suitable graphics tools supported by a physics package may be used. For more details, see [12] for examples.

2.2. Software-augmented hardware

During development or adaptation of a robot hardware system for a given application, not all the hardware parts may be available. Therefore software simulating the missing parts can be used to represent, and in fact to experiment with, different designs for the missing parts. Often this kind of software is designed to be able to drive the missing hardware part as well when and if it is later installed.

2.3. Software driving both simulator and hardware robot

Extending the above idea, when designing a simulator for a given robot architecture, it is often desirable for the same software to drive both the simulator and the actual robot. This way faithfulness of the software model to reality can be tested and the simulator can be used by multiple designers simultaneously to reduce expenditure on the robot. [12]

2.4. Robot Usage without Simulator

In this stage the robot is being used without a simulator either during development or actual intended use. Data may still be collected for subsequent analysis and evaluation. For example, data about the behaviour of various components such as sensors, actuators, movements of the components and the like may be collected analyzed for correctness and fluctuations over time.

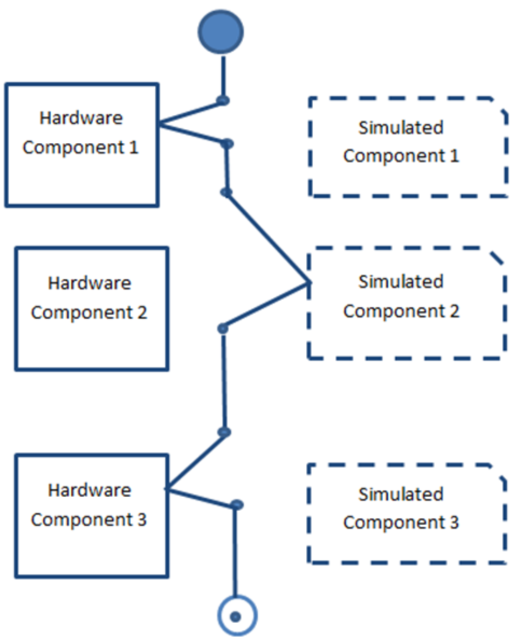

Figure 3. Structure of a robot containing hardware components and simulated components

In the above figure Hardware Component 2 has been switched off and Simulated Component 2 has been switched on in its place.

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3. Training of Software

To increase the accuracy of the simulation software, it may be necessary to collect data from the actual hardware and train the software based on data collected from itself by comparing it with data from the hardware by using methods of “supervised training” from the field of data mining and artificial intelligence. This may be used to improve the vision, object recognition, path selection speech recognition,and similar capabilities of the robot. If no such data for the hardware is available, methods of “unsupervised training” need to be used, which are usually less accurate and have lower levels of confidence [2].

4. Mapping of Software Structure to Architecture & Design Patterns

Another concept that can be brought to bear in software development is the concept of architectural and design patterns [18] . Since a given family of robots will have similar sets of reasoning and acting abilities, these patterns can be created and stored in a library, or better yet in an ontology [13], to simplify software development. Studies have been done to facilitate mobile robot software knowledge reuse by capturing conceptual models. These studies may be included in a robotics software engineering curriculum to illustrate techniques for reusing robot software knowledge. [3]

5. Seperation of Concerns

One of the problems in the application of system enginering techniques to robot design and development has been identified as “seperation of concerns” [1], an issue familiar to software engineers. The issue has been raised as a contributor to the current lack of expected levels of achievements of “robot performance in real world environments”. We do not replicate the issue here but wish to bring up its consideration in a robotics software engineering course curriculum. Interested readers can access the details in the referenced publication.

6. Managing Fuzz

A concept that robotic software developers come in contact with is that of so-called “fuzz”. In robotics “fuzz” refers to complex uncertainties in the state of the robot or robot group that come about due to minute inaccuracies the responses of hardware and software in the actual robot or simulated robot. These inaccuracies can occur in the performance and measurements of real or simulated mechanical movements, forces and energies involved, part specifications, materials, the environment, and electronic/electrical fluctiuations in the parts and measurements. When such inaccuracies are compounded, they may be difficult to isolate and keep within allowable ranges.

Another complex issue here is the optimization of deviations due to fuzz and sensitivity of measurements. This is likely to be one of the most time-consuming parts of the project due to the uncertainties in the nature of data collected, hence the word “fuzz”. Thus, careful experiment design and collection of relevant data of sufficient accuracy is of utmost importance. This topic can be briefly presented in the initial course with more complex topics introduced in advanced, multi-discipline courses. For a broad overview of the subject and a good reference list see [10].

7. Data management, experiment repeatability, performance analysis and evaluation

As is apparent from the preceding, effective data collection is very important to achieve optimum behaviour from the robot. This means using proper tools and techniques needed to obtain correct results from the experiments. These may include simple sequential files, indexed files, relational databases, probabilistic data in ontologies[13] and other formats. Sufficient repetitions of experiments should be made until the above analyses produce results with required levels of statistical confidence for the particular application. [2]. For even better analysis, results obtained from the above data should be compared with new data obtained independently.

8. User Interfaces

Several types of user interfaces are needed, such as interfaces to:

(i) Develop the software, including interfaces to available, existing software or the framework being used. Typically a library to house the collected data in the form an ontology including heuristic data analysis and modelling capabilities should be available

(ii) Run the software/hardware robot system, including interfaces for data collection, perhaps in online and offline status due to length of runs

(iii) Analyze data and generate needed reports,

(iv) Make needed software modifications through interface type (i) above.

Requirements and use-case design analyses of the interfaces should be made early and used to guide their development [14].

9. Documentation and Reengineering

An important part of engineering education is to create technically sound and easily understandable documentation for one's work. This is especially true for projects. The instructor should plan the content and format for standard student projects. The conformance of the projects to this format should be a part of the project evaluation. Reengineering often appears as extensions or changes to the content of the project as delivered. Hence, if the project can be re-engineered easily and succesfully, it is a sign that the project is well-structured and documented. For robotics software, documentation should address subjects in different fields of engineering, overall system views of robots and experimental data related to the robot.

10. Teamwork

Teamwork in undergraduate projects is very important to give students experience in working with colleagues to obtain the desired results. So the work plan for the project should be designed to give every member of the group a significant role in all phases of the project mentioned in the beginning of the paper. Sometimes this is hard to achieve due to schedule conflicts and differences in abilities and motivation levels of the team members. A robotics project is often a multi-disciplinary project, including subjects from several disciplines, as those disciplines are currently defined. Therefore, one approach is, where possible, team members should be given tasks closest to their disciplines. Another approach, which can be called the "mix-and-match" approach, may be for members of different backgrounds to work together on a given part of the project to increase their exposure to problems outside their specialties.

However, in all cases, the project and the documentation as mentioned above or as prescribed by the instructor should be completed to the instructor's satisfaction.

11. Sample Curricula Recommendations

11.1. Excerpt from ACM Computer Science Curricula 2013

"IS/Robotics[Elective]

Topics:

- Overview: problems and progresso State-of-the-art robot systems, including their sensors and an overview of their sensor processing
- Robot control architectures, e.g., deliberative vs. reactive control and Braitenberg vehicles
- World modeling and world models
- Inherent uncertainty in sensing and in control
- Configuration space and environmental maps
- Interpreting uncertain sensor data
- Localizing and mapping
- Navigation and control
- Motion planning
- Multiple-robot coordination

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Learning Outcomes:

1. List capabilities and limitations of today's state-of-the-art robot systems, including their sensors and the crucial sensor processing that informs those systems. [Familiarity]
2. Integrate sensors, actuators, and software into a robot designed to undertake some task. [Usage]
3. Program a robot to accomplish simple tasks using deliberative, reactive, and/or hybrid control architectures. [Usage]
4. Implement fundamental motion planning algorithms within a robot configuration space. [Usage]
5. Characterize the uncertainties associated with common robot sensors and actuators; articulate strategies for mitigating these uncertainties. [Familiarity]
6. List the differences among robots' representations of their external environment, including their strengths and shortcomings. [Familiarity]
7. Compare and contrast at least three strategies for robot navigation within known and/or unknown environments, including their strengths and shortcomings. [Assessment]
8. Describe at least one approach for coordinating the actions and sensing of several robots to accomplish a single task. [Familiarity]"

11.2. An excerpt from IEEE Robotics & Automation publication on Society & Education

"...Some introductory courses stress parallel processing from the outset (with traditional single threaded execution models being considered a special case of the more general parallel paradigm). While we believe this is an interesting model to consider in the long-term, we anticipate that introductory courses will still be dominated by the "single thread of execution" model (perhaps with the inclusion of GUI-based or robotic event-driven programming) for the foreseeable future. As more successful pedagogical approaches are developed to make parallel processing accessible to novice programmers, and paradigms for parallel programming become more commonplace, we expect to see more elements of parallel programming appearing in introductory courses."

12. Conclusions

Despite the current nascent state of robotic software engineering, software engineering education should include introductory material in this area, with possibly more advanced material in specific courses on the subject. One of the problems will be to keep these courses up-to-date with the rapid introduction of new robot technologies and related engineering methodologies. While we have above delved into many aspects of robotics software engineering, not all aspects can be addressed in an introductory course. The burden, as usual, in on the instructor's shoulders to create a cohesive syllabus from these, and possibly other areas. In fact, a series of 2 or 3 courses covering robotics software can be developed by extending the material above.

The trend toward on-line education programs will help in keeping course materials, including student projects, updated. This can be further helped by use of simulators of robots and robot teams whose software can be updated easily. In fact, student projects can be used to develop updates to the simulators. Laboratories with highly parallel architectures can be used to simulate robot groups and related control technologies while working on actual robots. Industries will want to subsidize research in their areas of production and even employee training. This will give more incentives to universities to create and expand research on robotic systems.

While it is hard to estimate the rate of progress in robotic software technology, we can expect that as we understand applications of this technology better, the success rate will be higher than the current rate, similar to applications of many new technologies in the past in such areas as in automotive, electronics and other engineering disciplines.

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The first year experience of using LEGO Mindstorms robots in the Tallinn University of Technology outreach program for secondary and primary school learners

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Abstract

The number of secondary school graduates in Estonia has been dropping for some years now. Public universities are supported by the state according to the number of students studying. In that kind of atmosphere, all the universities are trying their best to attract potential students to enrol. Potential undergraduate students tend to think that engineering curriculums are too hard or they lack interest and understanding about the field. Therefore many young people prefer to enrol into more "softer" curriculums, but society still needs well qualified engineers, especially when the number of graduates is decreasing year after year. In order to encourage schoolchildren to consider career in engineering and raise their interest in technology, hands on programming workshop with Lego Mindstorms kits was developed as a part of an outreach program. The task of the workshop was to program a robot who follows a given line in competition against other teams. During the first year, almost 500 students participated in this kind of practical robotics lessons with ages 8 to 21. They were asked to fill out feedback forms. In this paper, the workshop structure and changes made to it during the first year of conducting the workshops are described. Students' answers according to their gender and age are analysed. Also, reasons behind the success of this project are discussed.

Keywords: *LEGO Mindstorms EV3, K-12, Outreach, Educational robotics, Workshop, Programming, Engineering education, Hands-on learning.*

1. Motivation

Estonian demographic situation is as follows: in the last five years (as seen in figure 1 and table 1) the number of people aged 18 and 19 (age of graduating secondary schools) in population has been decreasing and this process is not stopping. Therefore, the potential number of university students is also decreasing year after year. This trend is also visible when looking at admission data of three biggest universities in Estonia – Tallinn University of Technology (TUT), Tartu University (TU) and Tallinn University (TLU).

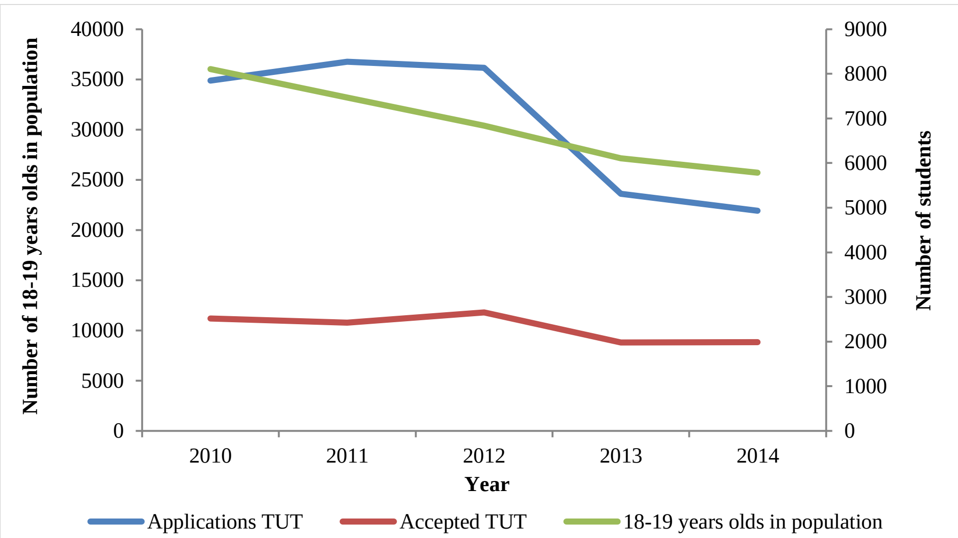

Figure 1. Number of people aged 18-19 in population (left axis) compared to annual number of students applying and annual number of accepted students (right axis) in Tallinn University of Technology.

Estonian government has done a lot in hopes to encourage students to attend universities. Thus from 2013-2014 academic year onwards, studying in public universities is free for everyone who passes admission requirements. Before that there were specific number of government supported free slots, but people were allowed to enrol and pay their own fees if they did not manage to get a free spot. This has now created a trend where more places are offered and not all of them are filled (see table 1).

Table 1. Annual number of student applications in three greatest universities of Estonia (TUT= Tallinn University of Technology, TU= Tartu University, TLU= Tallinn University) [1]-[5].

	2010	2011	2012	2013*	2014
18-19 years olds in population	36020	33210	30380	27149	25699
Applications TUT	7850	8268	8135	5314	4931
Accepted TUT	2515	2426	2652	1978	1990
Places TUT				2431	2430
Applications TU				8932	6988
Accepted TU	3550	2864	2626	2360	1990
Places TU	1592	1636	1663	2585	2415
Application TLU				7280	6423
Accepted TLU	2008	1963	2002	1967	1778
Places TLU**				1694	1504

*Education system changed in 2013 when higher education became free for all but at the same time, the government is still in a process of defining how many students in specific curriculums should be accepted.
**Some curricula have admission thresholds based on secondary school graduation exams

The decreasing number of students leaving unfilled places in universities is creating a situation where society is in a need for engineers, but students are afraid and have reluctance against STEM (Science, Technology, Engineering and Mathematics) fields. Especially, the ICT (information and communication technologies) sector is one of the fastest developing sectors of Estonian economy that has been described of having big cap between required and available workforce. In order to improve the situation, the non-profit association The Information Technology Foundation for Education (HITSA) was established. HITSA offers different grants for variety of activates to ensure better ICT education for all levels of education. [6]

Using grant from that foundation, the programming workshops for high school students were developed and implemented in Tallinn University of Technology (TUT). The aim of the workshops was to attract students who were about to finish secondary education, to consider continuing studies in STEM fields and give them hands on experience with similar practical tasks given for university students. Lego Mindstorms robots and software was chosen as it is easy to use, hides some of the complexity of programming and almost everyone has some kind of previous experience as they have come across regular Legos.

During the workshops, teachers showed interest and started to ask if similar workshops could be organized for primary school pupils and therefore respective workshops, outside the initial scope and support of the project, were conducted. Now after one year, the first results can be presented and conclusions on the impact of the project can be analysed.

2. Initial workshop structure

The structure of the workshop changed during the first year of conducting workshops according to the problems and needs risen from the practical implementation.

Students were provided with a kit of education EV3 Lego robots for a group. Groups usually consisted of 3 students – due to the limitation of available Lego kits. They had pre-built robots having two wheels (controlled by two separate motors) and third support ball wheel. These pre-built robots were also equipped with four sensors – gyro, infrared, touch and colour sensor, as seen on figure 2. Usage of all of those four sensors was embodied into the task of the workshop.

The task of the workshop was to solve a simple line following exercise. Students start with robot facing them. After clicking touch sensor, robot turns 180 degrees and starts following the black line on a white background. Colour sensor, pointed down, was used to follow the line. Touch sensor was used to mark the start – students were asked to program their robot so that it will not start moving before touch sensor's state has changed. Gyro sensor was used to turn the robot after the start. Infrared sensor was used for extra tasks for the fastest students so that

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after finishing the line following race, they could continue driving towards infrared beacon and stop when beacon is in distance of five centimetres from them.

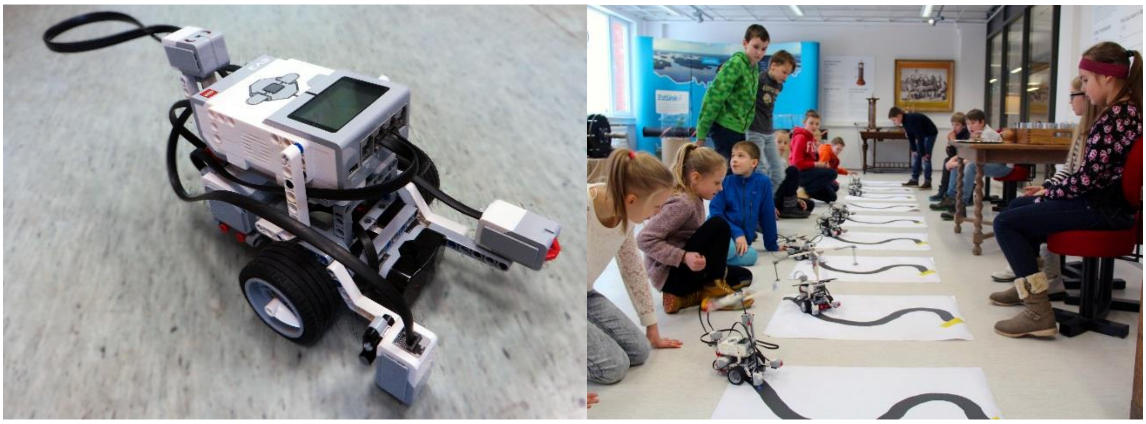
Figure 2. Pre-built robot used in workshop (left) and racing in workshop (right)

The workshops started as 1 hour long sessions where students only programmed. At the start, for the first 5 minutes, presentation was given about robot sensors and general movement - different options how to turn the robot and how much space it takes. It also covered some common robotics problems like odometry. Then, about 10 minutes was spent covering programming, such as robot movements and program flow elements in Lego Mindstorms software. Then the tasks were introduced, including general idea of using zigzag movement for line following. Students were given half an hour to come up with the program. In order to have more engagement and motivate students, workshop ended with a race between teams. It was known for the participants from the start.

The following structure was developed, considering that the tasks should be easy to program, visually impressive and have a fast feedback. Students should be able to see quickly how the blocks they are dragging and dropping in software affect robot’s behaviour.

Lego Mindstorms software was suitable for this kind of workshop as it is fairly easy to use – students only need to drag and drop elements and adjust the parameters of those blocks. It was expected that majority of workshop participants do not have any previous programming experience and to teach them to code with an hour is not feasible.

2.1. Initial feedback and experience

The first generation of workshops were only used with secondary school students attending the class via HITSA supported grant. Workshops took place in three major cities of Estonia connected with university organized open-door days in TUT and in its colleges. Majority of the workshops were done in Estonian, with an exception of two sessions conducted in English with simultaneous translation into Russian by another person, because the attendance studied in Russian speaking schools and lacked proficiency with Estonian language.

In total 189 students aged 16-21, as seen on figure 3, attended 15 workshops held during first half of 2014. Number of collected feedback forms was 134 (71%). Majority of the attendants had one more year of studies ahead of them before finishing the secondary school. That level of studies was declared by project’s heads as the most appropriate to achieve interest in studying ICT subjects.

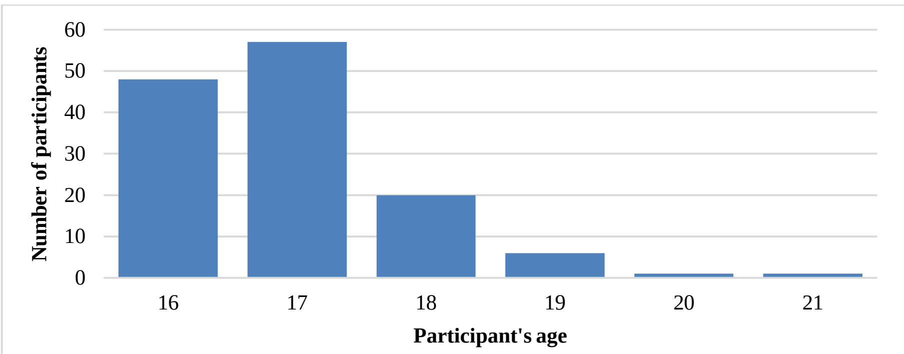

Figure 3. Workshops Age distribution of the participants of the first version of the workshops.

When holding the workshops, it was clear that one hour was not enough. Students wanted to spend more time programming their robots. It felt like all the theoretical information and introduction of programming had to be performed in very rushed manner in order to stay inside the time limit.

Written feedback was collected from students. They were handed small form with 10 questions about their interest, their experience in the workshop and their previous experience with programming and robotics. Feedback also showed strongly that students wanted to spend some time building the robots. Also, it became clear that students, even in high school, are not able to program totally independently. They needed a lot of guidance and help and it took a lot of effort from the support personnel to help each and every group with similar questions and problems.

The race at the workshop proved to be a real success – students got really excited when they heard there is going to be a competition. It was graded in feedback to be encouraging factor despite our fears that it might scare participants. Also, between races, as all the teams were racing with each other two at the time, students tended to go back to their program and tried to improve their speed.

Only few times, the extra task with infrared sensor was done by few groups, usually containing people who already had Lego Mindstorms and/or programming experience. Other teams did not just have the time to concentrate on anything else than line following.

44% of those who filled the feedback forms had previous programming experience. 28% had some kind of previous experience with Lego robots. It could have been expected, due to the workshops taking place during open-door days of TUT, that those students who took their time to come, already had some interest in ICT field and they wanted to know more.

Feedback showed that participants agreed that the workshop was too short (with average grade of 4.0 in scale of 1(enough) to 5 (not enough) time). Students described the tasks to be engaging and exciting and graded the interest in task with 4.5 (in scale 1 to be boring and 5 very exciting). Students' opinions on the difficulty of the task varied with average grade of 3.1 (in scale 1 easy to 5 really hard).

If asked how student felt about their interest towards programming, robotics and technology in general, majority described those indicators with high grade. Using Apriori algorithm to obtain associated rules, it became visible from the feedback forms that those students who had started with a high interest in one of the asked fields (robotics, programming and technology), also marked other fields with a high grade. It only happened a few times when a student had lot of interest in only one field and graded rest of the fields with lower marks. Those who found the workshop to be interesting, usually did not complain about the difficulty level of the task. Also, those students tended to grade their interest towards robotics with higher grade than the rest. In addition, it became visible, that those students who had previous experience with programing, on average, found the task to be more exciting than those without previous contact with programming.

3. Second version of workshop

Due to high interests from teachers who contacted the workshop conductors or university, workshop was modified according to first lessons learned with 15 groups. Workshop was now offered in TUT main campus for schoolchildren of all ages.

The first major change was that workshop was extended to become 2 hours long (expect workshops organized via HITSA project where workshop was extended to 1.5 hours). This way participants have more time to program and theoretical background can be explained in more detail without rushing. The time to build robots was assimilated into the workshop schedule. More kits were obtained and groups could be reduced to 2 people.

New format of the workshop meant that it started with 5 minutes of general introduction about Lego Mindstorms robots, followed by around 25-35 minutes of building. Sensors were removed from the design of robot used in initial workshops and slides with building instructions generated with Lego Digital Design software were offered for teams, so that everyone can build in their own tempo.

Then general introduction of robot and sensors was offered, continued with programming introductions. General robot's sensors introduction was done now in a way that all sensors were introduced with real life connection. For example, participants already pointed out that colour sensor reminded them camera and they had no trouble comprehending how it works. Gyro sensor was now explained with connection to tablets and smartphones that even children as young as 8 years tend to own.

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Depending on participants' age and previous experience, programming introductions might have been very vague as it became clear soon that explaining flow concepts (like loop, switch etc) for younger participants was not profitable. These concepts are too abstract for them to comprehend in classical lecture mode. Also, as those younger participants who saw the programming probably for the first time in their life, solving the task independently proved to be too much. It was decided that the general program will be done together in tutorial format. The instructor in workshop explains the tasks and builds the program, step by step and participants follow. This format enabled to explain more conceptual flow blocks better as students were able to try them out instantly and actually see what those concepts meant and how they work in action.

The general instructions and programming intro was planned around 5-10 minutes that continued with program building and further continued with programming in tutorial format. Programming was divided into steps according to the task. First, it was programmed that robot starts to move only when touch sensor is pushed. Then robot is made to turn and last part contains line following in loop with switch usage.

The reason why the task was divided into subtasks, was to let participants see as quickly as possible robot's reaction to their program, so that they could get a better understanding of what one or another block in software does. This helped instructor to find incorrect programs as early as possible.

Line following was done with zig-zag principle. First it was programmed with only one motor moving at the time, with very low speed, so that students could visually follow what their robot does on the track and how the line following is achieved. Then, as everyone wants to have a faster race robot, students were encouraged to play with different speed options and test them on the track, on their own speed, to see how much difference changing the parameters can make. It is also very exciting that on largest speed robot actually becomes slower as the movements are so fast that most of the time goes into processing. When students encounter that kind of result, they start to come out with reasons why that kind of phenomena might be happening.

After around 5 minutes of testing the parameters, workshop continued with enchanting the program. Large motor block was replaced with move tank block that allows two motors to be controlled simultaneously and therefore allowing greater speeds. This creates a much harder situation for experimenting with parameters as two speeds have to be considered and robots tend to get inaccurate on larger speeds.

Finally it was explained that so far, between every movement, robot had been breaking and blocks are configured so that they are in continuous movement without breaking and this is how fastest speed is achieved.

In order to let everyone race and test their program whenever they want, instead of using two tracks, now a track for every team is offered. The workshop finished with working in team – one person filled the feedback form and the other one dissembled their additions to robots. When one person was done with the feedback, they switched. Also, workshop has now more detailed online feedback form.

3.1. Feedback and experience

In total 272 students from 21 groups participated on the workshops with new format at the second half of 2014 as seen on figure 4. Those workshops were attended in: conjunction with school visiting university (15), workshop implemented in conjunction with HITSA project (2), someone having a birthday party in university innovation centre (3) and charity Christmas party for kids with cancer (1 group). One workshop was done in Russian using translator, others were in Estonian. 267 (98%) of attendants filled out the feedback forms.

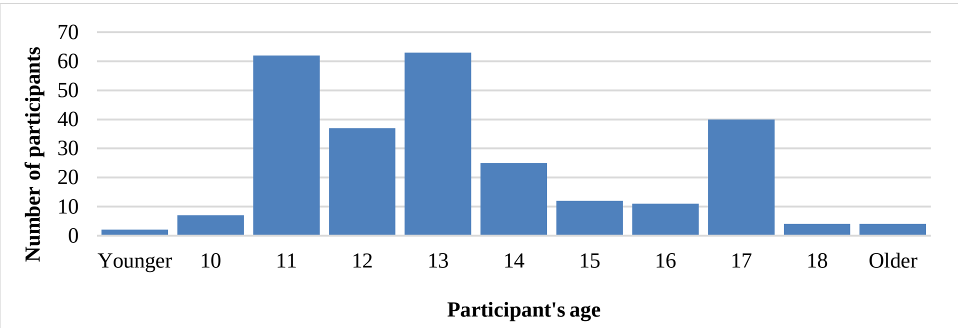

Figure 4. Age distribution of the participants of the second version of the workshops

13 out 21 groups contained mixed gender students. 1 group had only girls and 7 contained only boys. It became visible that when schools where coming to visit university and attended the workshops, teachers divided the class

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in half – mostly only boys were sent to Lego workshop (75% of participants were boys, 25% girls). With one group, teacher had split the group according to gender, but three girls still wanted to come to Lego and an exception was made in their case by the teacher. This kind on gender inequality and teacher's presumption that only boys like robots and technology was unexpected by workshop's implementers.

The feedback according to gender shows that girls mostly had less previous experience with programming and robotics than boys had (42% of boys vs 16% girls had previous programming experience and 40% of boys vs 21% of girls had previous experience with robots or robotics). Most common previous experience came from having current or previous Lego Mindstorms set at home or attending robotics club in school. Some participants had been on this or some other workshop beforehand. Two boys (ages 11 and 16) stated that they have used other programming languages before.

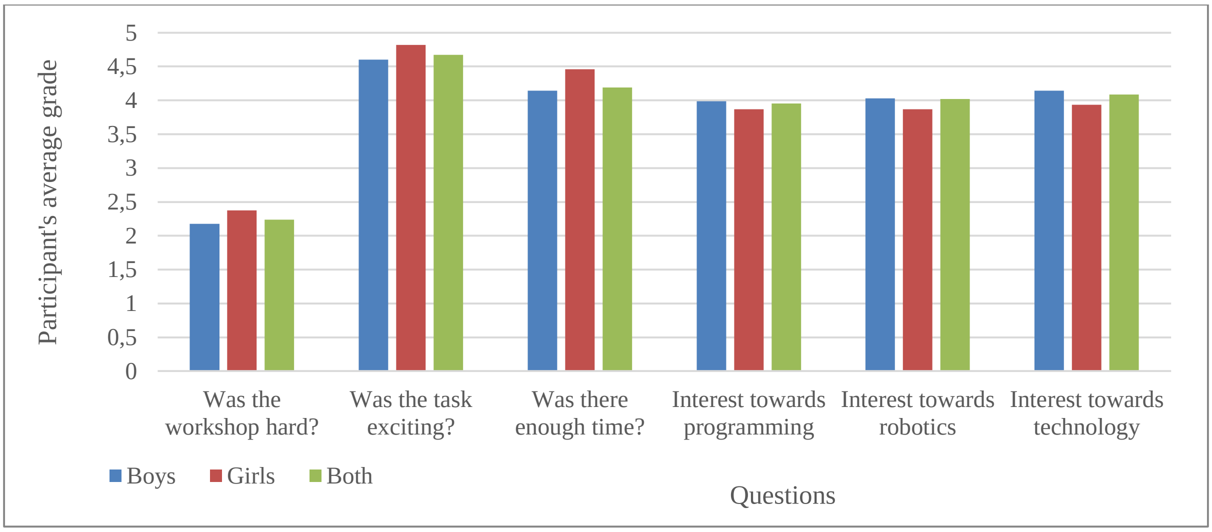

Figure 5. Selected answers from feedback form according to genre (scale from 1 (low) to 5 (high))

If teachers thought that girls might not find Lego workshop interesting, then feedback erases this assumption as seen on Figure 5. Workshop's interest factor was graded really highly by both genders with 5 (highest grade in scale 1 to 5) being the mode. Girls stated more often that they would have wanted to program even more (51% of girls vs 46% of boys). So it could be concluded that it actually did not matter if the participant was boy or a girl.

Comparing workshop's version 2 with version 1 answers, participants were now happier with time available. Also, grades about how much interest they now have towards robotics, programming and technology in general were all up with grade 5 now being the mode (instead of 4 in previous version).

When looking at age groups, some interesting patterns emerge as seen on figure 6. Surprisingly, the youngest group says the workshop was the easiest. Also, the youngest group seems to have most previous experience with robotics with 52% of answers from that group stating that they had some kind of contact with robots before. Second age group (12-13 years old) have had least previous contact with robots with only 27%.

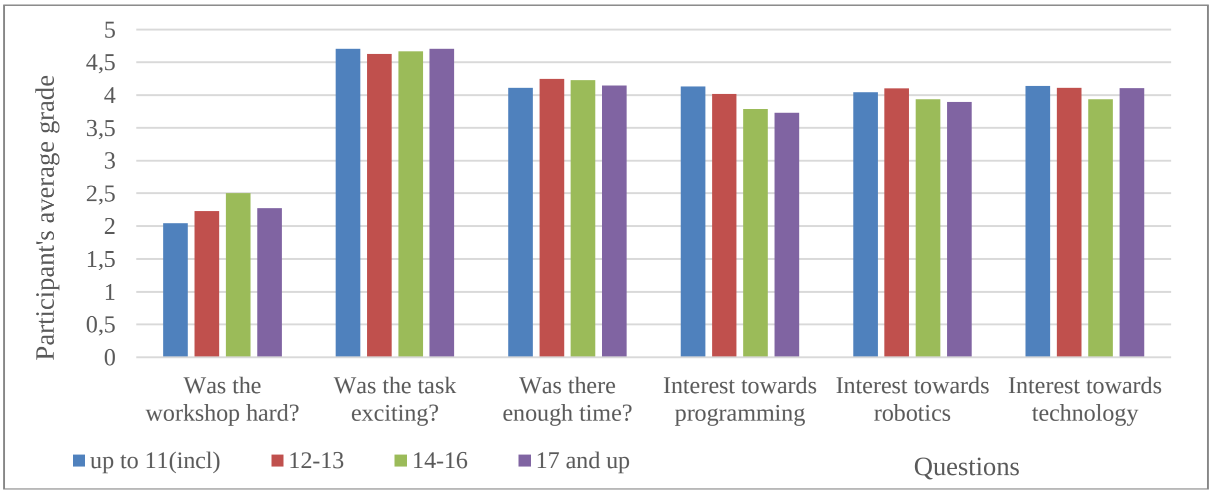

Figure 6. Selected answers from feedback form according to age group

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Second age group is also the one to state that their average last contact with any kind of Lego was between 3 months to one year. For all other age groups the average was between 1 month to 3 months, showing that even older students have had some kind of contact with Legos throughout their school years, despite general assumptions.

Better feedback collection came due to switching over to computer based feedback forms that were faster. Also, more detailed questions about students' experience and interests were added. First version of feedback concentrated mostly on improving the workshop then now the focus switched on how much participants learn and how to improve the impact of the workshop.

With building now part of the workshop, new problem arose that some teams are really fast, but others needed more time. Thus some extra activities between building and programming had to be offered for the participants. First solution was to encourage students to decorate their robots with bricks, gears and wings available in the kit. Then, some students were very excited about another motor available in the kit and built impressive propeller for their robot. I found that idea to be very creative and I support allowing students to express their individuality and let them personalize the general robot. That became really popular and some really creative and clever designs emerged.

Using tutorial mode for building the program was a success. It enabled us to bring workshop to different ages and everyone was able to make their robot run. During the workshops there were no teams that could not manage to get at least one run out in the track. Surprisingly, it did not made too much difference on instructor's side, if the participants were younger or older. The only variance was how programming concepts were introduced. Secondary school students were given a small lecture about programming and were later encouraged to solve the tasks independently. With younger participants those concepts were demonstrated when blocks were used in programming part of the workshop, so that they could visually follow what those blocks do.

4. Further Work

Schools' interest towards the workshops have been high and therefore conducting the workshops has not been finished, despite the end of the initial project. To current date (end of March) another 24 groups have already attended the workshops.

During the workshops, research question of how different age groups understand and comprehend different programming blocks arose. Therefore feedback questionnaire was even further developed to include multiple choice questions about programming blocks. Some of those answers were obviously wrong, others reflected different levels of understanding about concepts. For example, answer might be right in context of current exercise, but that conclusion cannot be deducted in general case. Other answers might have been right in concept level, but students might not have realized it in context of the current workshop.

Also, section asking about students' previous interest in programming, robotics and technology in general was added so that the effect the workshop had on student could be analysed. That kind of modified feedback has been used in the second year of conducting the workshops.

Furthermore, the workshop structure has been modified to third version, mainly to lower the time students spend building with Legos and to facilitate longer time to fill out more profound feedback form. Also, some modifications to the task taken from verbal or written suggestions from students have been implemented. Due to interest and some groups wanting to visit the workshop more than once, advanced workshop using space challenge matt has been started.

In addition to current analyses, it is planned to see if language of the group, geographical location of the school or if the school is considered to be elite school makes any difference in grading the workshop or understanding the programming blocks.

5. Conclusion

Despite the project being first directed to secondary school students, currently the majority of participants are 11-13 years old which is also deemed to be the most suitable age to initiate interest in STEM subjects. The popularity of the workshop has been surprising as when those workshops became available for schools visiting the university, it was expected that in most positive presumption a group per week attends the workshop. In many cases, it has been many groups attending in the same week or even in the same day. School break has proven to be the most popular time frame.

Also, feedback has shown that gender does not matter if students excitement and engagement in workshop is considered, despite teachers having the presumption that girls would be bored in that kind of workshop. Furthermore, age seems not to be a factor for students to enjoy robot building and programming – something the implementers of the workshop were not sure at the beginning and the project who started these workshops, would not even consider.

It could be debated if offering that kind of workshops for students aged 11-13 has any impact on their later choice when applying to university or if the workshops should have been kept exclusively for high school students who are more likely to understand concepts behind methods used in workshop. With current limitations for this research, there is no possibility to assess this factor.

Most of the changes to the workshop's structure and task have been done from experience when actually conducting the workshops or from students' feedback. It is very hard for someone older than those participants to know precisely what they will want and what they will like. Building propellers was idea solely taken from students' input that proved to be very popular. It concentrated on what participants of that age found most exciting – it was visual and they could see the effect of having that extra structure on their robot. It also enabled them to show creativity as no common building instructions were offered. Some students really excelled with thinking of their own design, but others lacked imagination to start from zero – that problem was addressed in third version of workshop. Also, playing sound and doing victory laps at the end of the race was an idea taken from students and added to the workshop. Especially the younger groups have enjoyed adding sounds and if they seem to have hard time coping with apprehension of other programming blocks, then sound and how to change the parameters seems one thing that everyone can do independently at the end of the workshop. It proves once again that if participant sees the effect of the block in real life, it is easily understandable and more engaging and they are more likely to remember how and why to use it later.

The workshops can be considered to be success due to very positive feedback scores from participants, constant change according to experience, attitudes and wishes from students and large number of groups showing interest and participating in workshops.

Also, it can be concluded that having a race in the workshop seems to be very motivating force as attitude of the school children seems to be that they want to be the best. Furthermore, there have been cases of participants being very sceptic at first, but then warming up towards the task and workshop. Maybe this case represents it in best way: one boy was very unhappy about being forced by the teacher to participate in workshop as he stated he would never consider science curriculum and he hates everything that has anything to do with math. During the workshop he got super excited about making his robot go faster, put lot of effort into tuning his program's parameters and when it was time to go, he was the last to leave. His classmate commented: "And you did not even want to come. Now we have to wait after you."

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Undergraduate Curriculum in Robotics

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Abstract

Robotics is a branch of mechanical engineering, electrical engineering and computer science that deals with the design, construction, operation, and application of robots, as well as computer systems for their control, sensory feedback, and information processing. It is difficult for mechanical undergraduates to fully understand and build up a real robot in a one-semester course. The goal of the course "Kinematics of Robotics" is try to let students know basic theory in robot and practice of robotics engineering. This paper shares the experience in teaching this course. In the beginning of the course, students will be introduced to the foundational concepts of robotics such as kinematics, dynamics, control, and programming. Then, students' knowledge of sensors and motors is integrated with programming logic as they perform complex tasks using LEGO® MINDSTORMS® NXT robots and software. Through two lab work assignments and final competition, students will be familiar with the steps of the engineering design process and come to understand how science, technology, mathematics and engineering—including computer programming—are used to tackle final competition and help people solve real problems. The most convincing achievement of this course is that one group of students attended the 2013 World Robot Olympiad (WRO) college category (Mars Colony) competition on 15-17 November, 2013 in Jakarta, Indonesia, and won the first place.

Keywords: *robotics, kinematics, sensors, programming logic, LEGO® MIDSTORMS® NXT*

1. Introduction

Learning is always assisted by hand-on activity, especially in the engineering field. This allows students to learn by their own action and their own mistakes and by the theory they have learned in action. Robotics is a branch of mechanical engineering, electrical engineering and computer science that deals with the design, construction, operation, and application of robots, as well as computer systems for their control, sensory feedback, and information processing. The connection of robotic physical actions to more abstract computation creates effective feedback for learning [1]-[3]. Because of the variety of concepts that robots engender, they have become a valuable tool for teaching the practical, hands-on application of concepts in various engineering and science topics [4]-[11].

It is difficult for mechanical undergraduates to fully understand and build up a real robot in a one-semester course. In the college junior-level course: *Kinematics of Robotics*, students use LEGO® MINDSTORMS® and LabVIEW™ to design and build their own robot. The LEGO® MINDSTORMS® series are used widely in many educational institutes [12]-[18]. Because LEGO® MINDSTORMS® is relatively inexpensive, reusable, modular, robust, configurable, and programmable, many educational institutes have already used LEGO® MINDSTORMS® for teaching robotics, programming languages, control systems, and computer engineering to undergraduate students as well as children. LabVIEW™ is a programming environment suitable for undergraduate engineering education. It offers support for data acquisition hardware, built-in libraries, multitasking, and simple definition of user interfaces and is widely used in professional engineering [18].

The goals of this course are:

1. To learn about the foundational concepts of robotics

2. To provide a hands-on experience to practical robotics

3. To learn about integrated system design, and

4. To learn about group dynamics and teamwork.

This paper shares the experience in teaching this course. In the beginning of the course, students will be introduced to the foundational concepts of robotics such as kinematics, dynamics, control, and programming.

Then, students' knowledge of sensors and motors is integrated with programming logic as they perform complex tasks using LEGO® MINDSTORMS® NXT robots and LabVIEW™ software. Through three design challenges, students will be familiar with the steps of the engineering design process and come to understand how science, technology, mathematics and engineering—including computer programming—are used to tackle design challenges and help people solve real problems.

2. Course Description

This course is designed for college junior-level mechanical engineering students, because they have already learned most fundamental courses for robotics such as *Automatic Control*, *Electrical Engineering* (*Circuits*) *Mechanisms and Dynamics of Machinery*, *Dynamics*, *Machine Design Theory*, and *Computer Programming*. The course is divided into two parallel instructional tracks: lecture and lab work.

2.1. Lecture

The lecture portion of the course meets two hours per week. Lecture topics include spatial descriptions and transformation, manipulator kinematics, inverse manipulator kinematics, Jacobians: velocities and static forces, manipulator dynamics, trajectory generation, manipulator-mechanism design, and linear control of manipulator. The main goal of the lecture series is to let the students understand the foundational concept of robotics. Instead of the original NXT-G software provided by LEGO® Mindstorms®, the students are requested to write program using LabVIEW™. Hence, during the lecture portion, how to use LabVIEW™ for programming is being taught. The lecture materials are based on the text [19], [20].

2.2. Lab Work with LEGO® MINDSTORMS® NXT and LabVIEW™

The lab work portion of the course is one to two hours per week. In the lab work project-based learning is used to develop structured programming, construction of robot mechanism, and logical strategies planning. It also develops students' confidence and interpersonal skill.

In the lab work, three to four students are working together to form a team (students are freely to choose their own team members). Each team has a complete set of LEGO® MINDSTORMS® NXT, which includes one intelligent brick, three servo motors, one sound sensor, one light sensor, one ultrasonic sensor, two touch sensors, and a variety of mechanical components (as shown in Fig. 1). Also, each team has to prepare a notebook PC – installed with LabVIEW™ software. The first lab work assignment is given in the first four weeks. The students have to build a robot which can walk through a 3 m long and 40 cm width track back and forth without hit the walls surrounded. The goal for this assignment is to help the students be familiar with the LEGO® MINDSTORMS® NXT and learn to use LEGO to construct the robot and program in LabVIEW™ to control it.

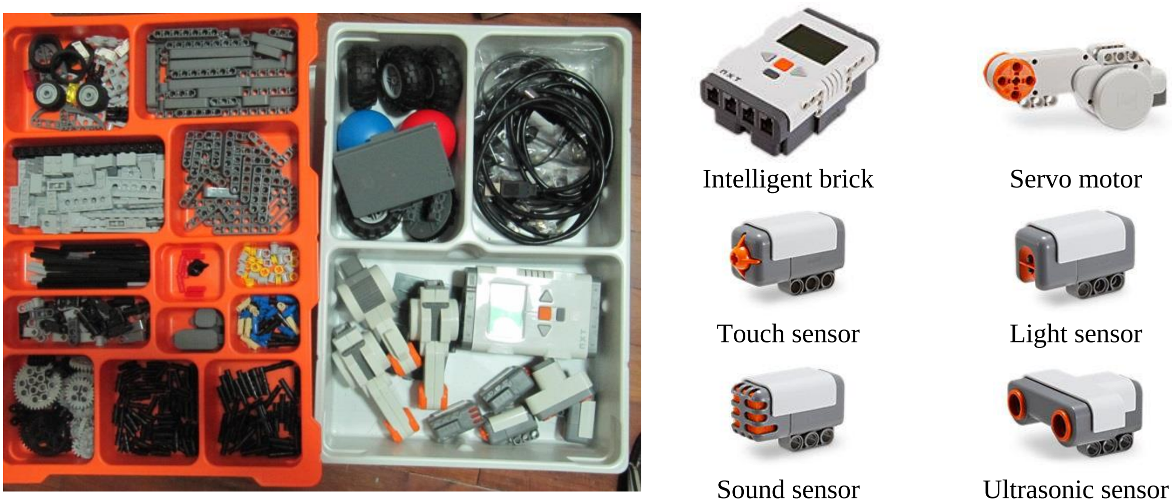

Figure 1. LEGO® MINDSTORMS® NXT kit

The second assignment is given at the middle of the semester. The robot should be able to move from the starting point to the middle track and knock down the 1^{st} bawling bar without hit the 2^{nd} bar. Finally, it should be able to move to the end point without touch the walls surrounding around the 3^{rd} track (as shown in Fig. 2). The

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goal of this assignment is help the students be familiar with the using sensors such as ultrasonic sensor, touch sensor, light sensor. Figure 3 shows two robots built by the students for the 2nd assignment.

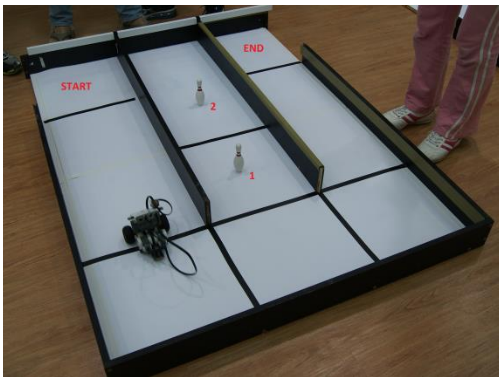


Figure 2. Second assignment – Maze

Figure 3. Robots for the 2nd assignment

2.3. Final Competition

As a complement to directed lab work, a competition is held at end of the semester. The goal of this competition is to maintain a high student motivation during the course, provoke team work, and foster students' ability to cope with problems. The competition is called "Smash Triathlon," the robot should be able to knock down three *Coke-Cola*® cans in sequence, and cross over six different obstacle zones, which are hill, slop, tunnel, narrowed road, unruffled waters, and turbulent waters, within two minutes. These obstacles are positioned randomly (as shown in Figs. 4 and 5). Each team can perform three times, so the best trial score is the one that counts. Students are free to build their robot configuration and the sensorial system. Figure 6 shows some examples built by the students for the final competition.

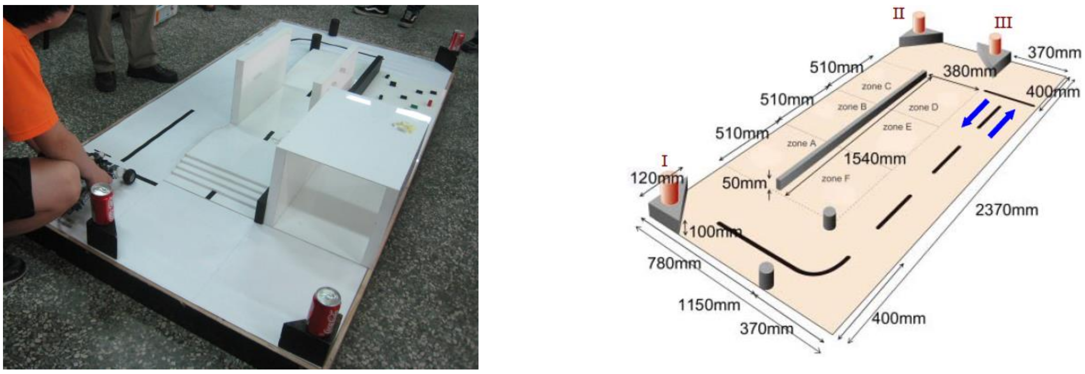
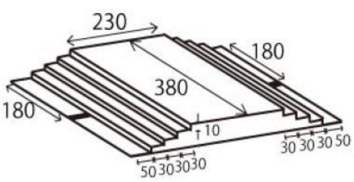
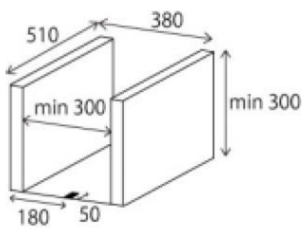


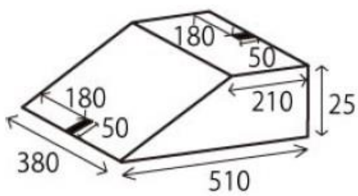
Figure 4. Final competition layout – Smash Triathlon [21]



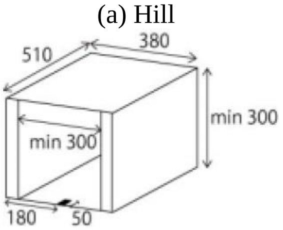
(a) Hill



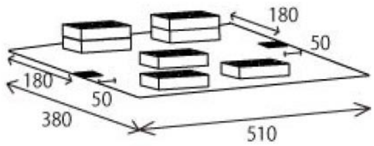
(b) Narrow road



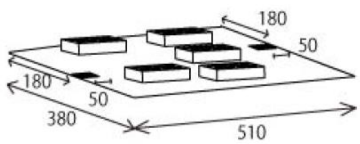
(c) Slop



(d) Tunnel



(e) Turbulent water



(f) Unruffled water

Figure 5. The obstacles for final competition (unit: mm) [21]

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Figure 6. Students with their robot in the final competition.

3. WRO2013 College Category (Mars Colony) Competition

In 2013, the World Robot Olympiad (WRO) announces the first time ever college category competition. One group of the students from this class decided to challenge this competition. They started to build the robot with LEGO® MINDSTORMS® NXT and components from MATRIX® Robotics System, and programming in LabVIEW™ during the summer break (from July to August). On September 2013, they attended the national competition in Taiwan and qualified for the world competition. The world competition is held on 15-17 November, 2013 in Jakarta, Indonesia. Total numbers of 19 teams from different countries and areas have competed in college category, and our team won the first place.

3.1. Mars Colony [22]

The mission of WRO2013 college category is that the robot is in charge of supplying several colonies on Mars with raw materials. Your company gets paid for your robot’s efficiency in doing so. The game field consists of 18 foam floor tiles in a 3 x 6 configuration. Black tiles consist of open field. Colored tiles will host way points for scoring elements. There is a white border surrounding the field that will act as a virtual border. The two sides of the field are separated by a 2” x 6” (35mm x 140mm or near equivalent) painted black to keep robots from wandering onto the other playing field (as shown in Fig. 7).

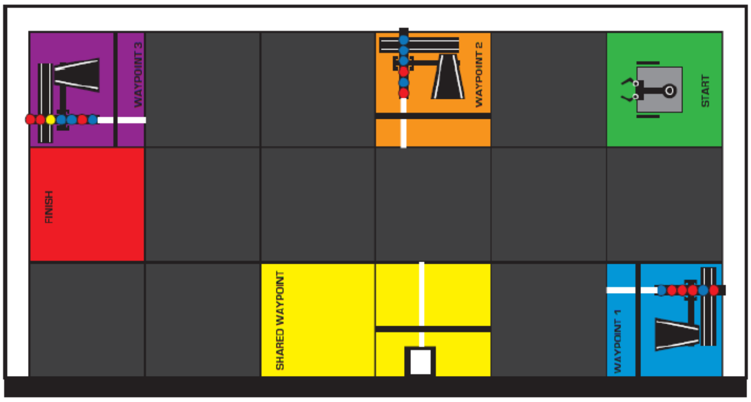

Figure 7. WRO2013 college category – Mars Colony [22].

Each way point has a variety of ways to detect its presence - Colored square on the floor or simply by running into it. Gameplay consists of harvesting Red, Blue, and Yellow Duplo Balls and putting them into scoring positions at various way points. Each way point will have a ball dispenser and a hopper to put balls in for scoring. Each way point represents a planetary factory that needs specific minerals more than others. Each ball will represent a specific mineral - Blue = Water, Red = Iron, Yellow = Gold. Balls are placed in waypoints in random order. Robots may only carry up to 3 balls at any one time. Each dispenser will have a different mechanism for that will require different actions to activate it. In waypoint 1, the dispense mechanism is crank. In waypoint 2, the dispense mechanism is pull. While, for waypoint 3, the dispense mechanism is push.

3.2. Robot Design

In order to accomplish the mission, students constructed the robot with the components from LEGO® MINDSTORMS® NXT and MATRIX® Robotics System, and programming in LabVIEW™. A compass sensor is used for finding the current position of the robot; while, a color sensor is used to accurate position the robot in front of each waypoint. For identifying the materials, another color sensor is installed in front of the separation gate, and the NXT controller will decide to keep it in the robot and deliver to other waypoint, or just deliver to the hopper.

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The arm is constructed in such a way that it can perform turning, pulling, and pushing motion to open the dispenser on each waypoint. Figure 8 shows the structure of this robot. Since the whole mission should be finished within five minutes, it is very important to plan the strategy to run the robot delivers not only correctly but also as quickly as possible to the waypoints for getting higher score. Figure 9 shows the robot with team members. Figure 10 shows serval robots built by other teams in the world competition.

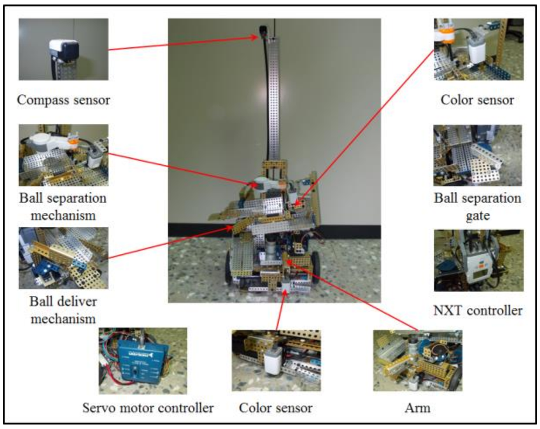

Figure 8. Robot for the WRO2013 college category

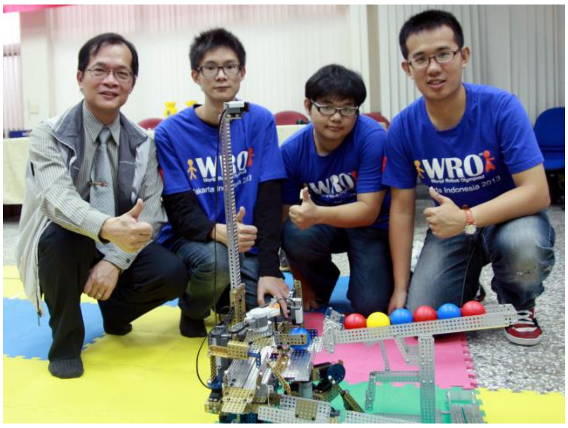
Figure 9. Team members with the robot.

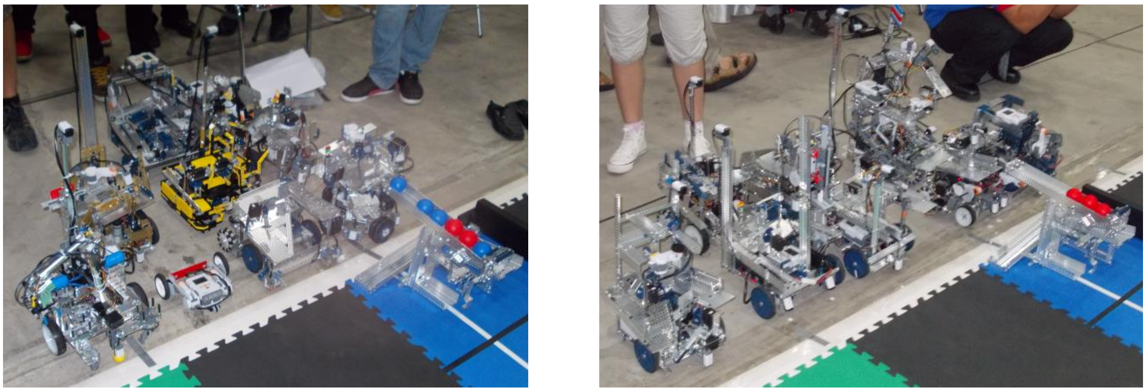
Figure 10. Robots in the world competition.

4. Conclusion

This paper share the experience in teaching "*Kinematics of Robotics*" for junior-level students majored in Mechanical Engineering. Beside regular lecture courses, lab work and student competition based on the use of LEGO® MINDSTORMS® NXT kits and LabVIEW™ are being included in the class. Instead of the default NXT Education software, programs were developed using standard LabVIEW™. Through two lab work assignments and final competition, students are familiar with the steps of the engineering design process and come to understand how science, technology, mathematics and engineering—including computer programming—are used to tackle final competition and help people solve real problems.

From an educational point of view, a high level motivation has been observed by the teacher, with the competition driving their interest in learning. Through the final competition, students have learned the way to combine lectures with lab work. The most convincing achievement of this course is that one group of students attended the 2013 World Robot Olympiad (WRO) college category (Mars Colony) competition on 15-17 November, 2013 in Jakarta, Indonesia, and won the first place.

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Poster/demo

ICEE 2015

A Blended Learning Signals and Systems Course

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Abstract

Signals and Systems is a mandatory course in 5 curricula in the area of Science and Technology of PUC-Rio. This course has shown a very high failing rate – many students drop out or cannot pass the exams. Due to its importance, since its is a prerequisite to many other courses in 3 of the curricula, faculty started using more ICT – Information and Communication Technology tools to enhance the course and motivate students. In 2014, the course started being offered in the blended learning mode. Faculty have closely been examining the changes in the performance of students as well as submitting questionnaires to assess their opinions and contributions to enhancements (there have been many!). Starting next March, it will be offered by the third time in this mode. The course is available from the Maxwell System (http://www.maxwell.vrac.puc-rio.br/) that combines a LMS – Learning Management System and an IR – Institutional Repository, among other functions. The online part of the course is made of various "pieces".

They are:

▪ Roteiro (Course Guide) – is a large html file that is the "context" of the course. It contains the basic concepts and links to a set of vídeos, interactive objects, animations, different types of texts all on the Maxwell System and to activities. It also links to external Open Access contents.
▪ Class Notes – a set of three volumes with topics of the syllabus used to complement the text book.
▪ Text documents that contain exercises to be solved, a concise MATLAB® manual with many exercises to solve and a set of .m files with routines, assignements, etc.

There are communication tools as well – discussion forums, chats, mailing lists, agenda, bulletin board, etc. An last but not least, a set of administrative tools to inform students on tests dates, grades, assignements, etc. The objective of this work is to demonstrate the online part of the course.

Keywords: Signals and systems, Blended learning, ICT supported learning, Courseware

Development and Evolution of A Capstone Project in Mechanical Engineering – A Twenty-Year Experience from Taiwan

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Abstract

As engineers are expected to be capable to define, to formulate and to solve an engineering problems, in particular industry-oriented problems as he/she graduates. While most university faculties focused on research-oriented training for engineering students, mainly because these faculties put most of their efforts in research, in the past decades. Many engineering graduates, especially in Asia, thus had difficult to adapt for industrial needs as they were lacking of training of the above-mentioned capabilities. This paper is intended to share experience on the development and evolution of the cirricurum on capstone project for junior and senior students major in mechanical engineering (ME) at the National Chung-Hsing University (NCHU). This cirricurum was designed in 1994 and started its first trial in 1995. To ensure students are able to learn the above-mentioned capabilities, the capstone project is designed that each team of students took a project designed by a faculty member with industrial experience. Each student is expected to explore the life cycle of a project, including the defining the scope, problem formulation, literature survey, exploring possible solutions, SWOT analysis of each solution, determining the best choice under course constraints, feasibility demonstration with paper or plastic models, detail design and analysis, selecting and purchasing commercial compoments and subassemblies, part fabrication, assembly, testing and adjusting. In the first couple years, industrial experienced lectures, together with faculties, are invited to teach students knowledge and techniques for project development, as these faculties have limited industrial experience. Accessment of student performance is another issue as grading standard may different among faculty members. The grading system is gradually modified with 60% group grade and 40% grade from the advisor in the past few years. The 60% group grade was graded by faculty groups based on student final exam, mid-term and final presentations as well as the year-end final exhibition and competition. The other 40% grade by the davisor is based the weekly progress reports, performance, attitude and the term report of each student. Student parents and other students at lower grades are invited to participate the final exhibition and give comments. Three alumni, each from industry, academia and research institute respectively, are invited to serve as the judges for the competition, which gives three awards to the highest grades. This capstone project curricurim has been highly praised in the acrredation on engineering education conducted by the Institute of Engineering Education Taiwan (IEET).

Keywords: capstone project, mechanical engineering, twenty-year experience.

Engineering Design Education based on the CDIO Approach

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Abstract

CDIO is a framework for an engineering education curriculum to train the next generation of engineers. The framework is based on students learning the processes for real-world system and product design. Through this framework, students will experience the CDIO approach of Conceiving, Designing, Implementing, and Operating. The standards indicated by CDIO are not fulfilled by a single course, but instead by fulfilling the guidelines by coordinating multiple subjects in the curriculum as a whole. Kanazawa Institute of Technology has two engineering design courses called Design Project I (PD1) and Design Project II (PD2). PD1 is held in the first semester in first year, and PD2 is held in the second semester of the second year. By experiencing project design with PD1 and PD2, students can learn about the Conceive and Design aspects of the CDIO approach. We then expanded the program, and made it possible for students to learn every aspect of the CDIO approach in PD2. This paper describes and evaluates a test implementation of this course.

Keywords: *Engineering Design Education, CDIO, Design Thinking*

1. Introduction

CDIO is a framework for an engineering education curriculum to train the next generation of engineers. The framework is a guideline for engineering education programs based on students learning the processes for real-world system and product design. Through this framework, students will experience the CDIO approach of Conceiving, Designing, Implementing, and Operating. These CDIO guidelines were developed in 2000 by an international project called the CDIO Initiative, with the goal of reforming engineering education, and the framework was completed in 2004. Currently, 115 higher education institutions in seven regions (Europe, North America, Asia, UK-Ireland, Latin America, Australia, New Zealand and Africa) have joined the CDIO Initiative, and CDIO is becoming a global standard as an engineering education guideline [1, 2]. Kanazawa Technical College was the first Japanese school to join CDIO, in December 2010. Kanazawa Institute of Technology (KIT) joined in June 2011.

Core courses for the engineering design education curriculum at KIT include Design Project I (PD1), Design Project II (PD2), and Design Project III (PD3). KIT has a two-semester school year, with PD1 held in the first semester of first year, PD2 held in second semester of second year, and PD3 (equivalent to graduation project) is held in fourth year. Each academic year has courses related to these core courses, making a curriculum that fulfills the CDIO guidelines overall. The author was a full-time teacher of PD1 and PD2 from 2001, and for 12 years was in charge of developing teaching materials and running the classes. For PD1 and PD2, students make teams and proceed with a project over the semester, learning about finding and solving problems. This is called Project-Based Learning (PBL) [3, 4]. The students' projects focus on actual real-world problems, and they work as a team to find a solution to those problems by gathering additional information in addition to the knowledge they already possess. Both PD1 and PD2 are each taken by approximately 1600 students, with approximately 300 projects underway during the semester for each course. Nothing of its like is seen in other schools [5-7].

This paper is about the student projects undertaken in PD1 and PD2 at KIT, from the perspective of engineering design process based on the CDIO approach, using the courses taught by the author from 2007 to 2010 as examples. When KIT students complete PD1 and PD2, they will have an understanding of the Conceive and Design (C-D) aspects of the CDIO approach [8]. This paper will consider what education is necessary to expand that to the Implement (C-D-I) aspect, or to both Implement and Operation (C-D-I-O) aspects.

2. Relation between the Engineering Design Process and the CDIO Approach

Figure 1 shows the relation between "PD1 and PD2 engineering design process" and "CDIO approach." The horizontal axis shows the engineering design process, and the vertical accesses shows the skills that learners should be acquiring according to the CDIO approach. PD1 and PD2 both have around 40 students per class. Each team is made of 5 to 7 students.

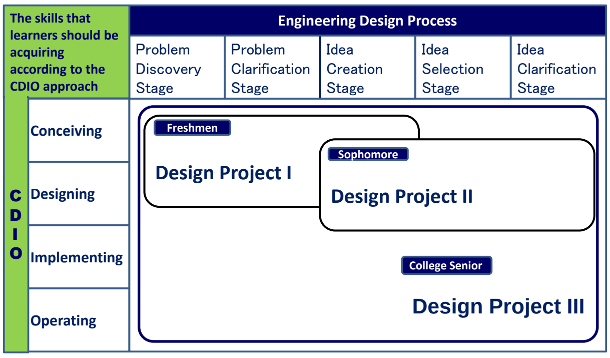

Figure 1. Relation between the KIT engineering design process and the CDIO approach.

Student teams engage in the following five stages as part of the project. PD1 and PD2 define these five stages as the engineering design process.
(1) Problem Discovery Stage: Find a problem that is worthwhile doing a project to solve.
(2) Problem Clarification Stage: With surveys of possible needs and the like, determine the actual nature of the problem. Clarify the people that problem relates to (users), and clarify the potential needs.
(3) Idea Creation Stage: Use brainstorming and the like to present multiple ideas.
(4) Idea Selection Stage: Develop a basis for evaluation of feasibility of ideas, and select the most feasible idea by member consensus.
(5) Idea Clarification Stage: Further develop the idea into something concrete to solve the problem. Next, examine the feasibility of that solution, and present the results with an oral presentation, poster, and report.

The PD1 project is mainly stages (1) to (3), and the PD2 project is mainly stages (3) to (5). For PD2, interesting projects are selected from PD1 reports and then continued. Therefore, for PD2 projects, some of the stages are overlapping. This means the first activity in PD2 is reviewing the results of PD1. However, some teams will approach new problems in PD2 (for example, problems suggested by local governments), and start from stage 2. Each semester at KIT is 15 weeks. Both PD1 and PD2 are worth 2 credits, and the project length is 15 weeks, with 90 minutes of lecture time per week.

3. Expanding the CDIO Approach from C-D to C-D-I or C-D-I-O

Considering the engineering design process in PD1 and PD2 at KIT from a CDIO perspective, Creative is equivalent to the Problem Discovery and Problem Clarification stages of the engineering design process. Design is equivalent to the Idea Creation, Idea Selection and Idea Clarification stages. In order to expand PD1 and PD2 to the I and O aspects of the CDIO approach, it would be necessary to create a "thing (product or system)" during the project, and then to operate it. This "thing" only needs to have a nearly complete solution, and be able to hold up to being actually operated. Therefore, it is necessary to have more prototype production in the Idea Clarification stage. For this prototype, we will include not only "things" made to discover any problems, but also documents indicating how using the "thing" would change users' lifestyles.

Figure 2 uses the example of designing a cup to display some of the ways it is possible for PD2 students to express a prototype, based on the author's experience. The methods of expression in the figure are communication drawing methods that are suggested to students during class [9]. These include taking the prototype cup (a) and investigating how it feels to use (b), examining what changes the cup will bring about in users' lifestyles (c), recording people using the cup and examining how it is used (d), taking physical measurements such as surface temperature of the cup when there is a drink in it and using those measurements for improvements (e), and consolidating all the data acquired to introduce the solution using a poster (f).

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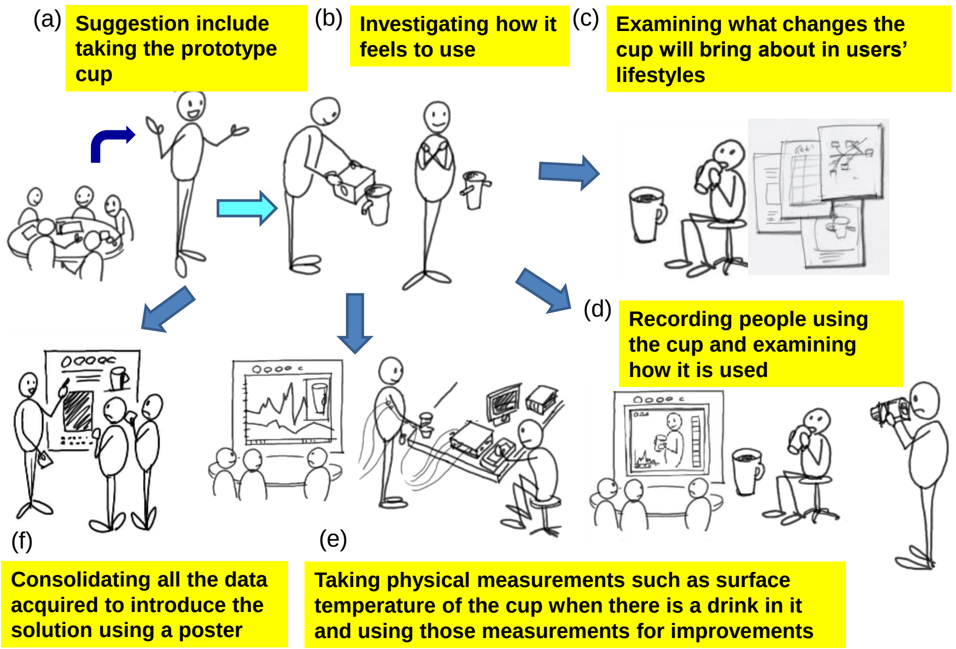

Figure 2. Diverse prototype expressions
(using a cup as an example).

Prototyping can be thought of as a hands-on method to develop ideas. Rather than showing the thing created to people, the true purpose is to make ideas more specific while making the prototype [7].

Figure 3 shows the flow of student projects for the engineering design process, and design activities must include constant feedback. If the project doesn't seem like it will satisfy user needs then the properties of those users should be observed again, or if it fulfills needs but there is still room for improvement in the solution then the idea can be refined. This feedback leads to balanced growth of the students' problem finding and problem solving skills.

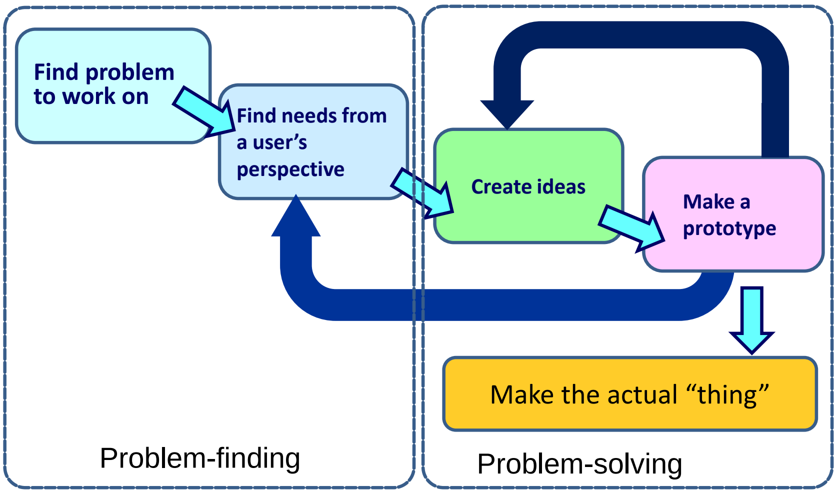

Figure 3. Flow of project.

Figure 4 is a prototype presented by students in PD1 in 2009, garbage tongs made out of cardboard. For PD1, showing the idea on paper with a figure is sufficient, but in order to demonstrate the practicality of their idea this team made a prototype of the tongs. The result was more than expected of PD1. By prototyping, students can rethink their ideas from the perspective of users, and quickly adjust projects that have focused too heavily on solving the problem. It also leads to learning balanced problem finding and problem solving skills. This example demonstrates these two points.

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Figure 4. Garbage tongs that make cleaning fun (Semester 1, 2009).

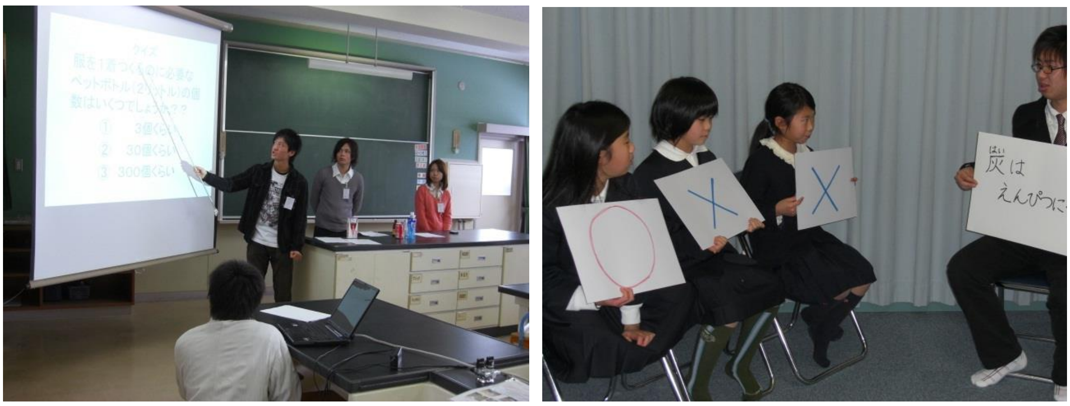
4. PD2 Course Examples and Evaluation

In the PD2 courses taught by the author so far, in some cases the student teams expanded their project activities from the C-D of the CDIO approach to C-D-I or C-D-I-O. Examples are discussed below.

4.1. Test Cases

Example 1: Creation of Environmental Education Program and Test Classes at Elementary School

Figure 5 shows a 2007 PD2 team that developed an environmental education program for elementary school students, and performed test runs of the classes at a local elementary school (Kanazawa Municipal Nuka Elementary School). For the Idea Clarification stage, this team negotiated with the elementary school to let them perform experimental classes. They performed one class for each of the three classes of Grade 4 students in the elementary school, participated in the school radio broadcast during lunch, and put up posters in the school in order to implement the environmental education program the team had proposed. These students made lesson plans, negotiated with the elementary school, and actually held classes, so they went through every aspect of the



(a) Class on the Earth’s environment in each Grade 4 class, (b) Appearance in school broadcast about the Earth's environment.

Figure 5. Develop environmental education program and implement it at elementary school (Kanazawa Municipal Nuka Elementary School, January 25, 2008).

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CDIO approach. If they implemented the education program at other schools as well and improved it, it would be possible to develop an education program closer to the ideal.

Example 2: Development of Community Bus Operation Support System and Internship

Figure 6 is an example of a 2008 PD2 student team that developed a system to support operation of community buses in the local area. Since 2003, PD2 has been receiving suggestions of problems from local governments. In 2008, this system was further developed, with the teams that worked on themes provided by the local government announcing their results in the city hall at the end of the semester. However, due to limitations on the time of presentation and using the space, only 60% of the teams working on local government themes (about 20 teams) are able to make presentations.

Figure 6. Student explaining system developed at internship results meeting
(Nonoichi City Hall, September 18, 2009).

The student in this figure drew the interest of city workers at this presentation, and as a third-year student (2009) joined the summer internship program at the city hall. Using this internship program, they experienced work at city hall and developed the system they had proposed to a degree that it could be put into practice. This figure shows the presentation of their results held in the city hall on the last day of their internship. This student was able to develop and implement the community bus operation support system they had made as a municipal service, so they achieved not just the C-D-I aspects of the CDIO approach, but even C-D-I-O. It is important to note that the knowledge the student learned in their third-year courses also contributed to developing this system during their internship. Being able to apply your education to society when appropriate, in other words practical engineering education, is the goal of CDIO.

Example 3: Support for Reading Books to Children with Handmade Picture Books

In order to carry out courses that fulfill all the aspects of the CDIO approach, it is necessary to develop a system for having people outside the school (stakeholders) evaluate the results of projects. After creating a “thing” near to completion, it is necessary to have a place to implement it. Figure 7 shows a 2010 PD2 project about reading handmade picture books to kindergarten children. This is an example where in order to demonstrate the efficacy

Figure 7. Create picture book and implement it at kindergarten
(Nonoichi Municipal Oshino Kindergarten, January 22, 2011)

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of the picture book they made during the Idea Clarification stage, the team visited Nonoichi Municipal Oshino Kindergarten and read the book to kindergartners.

An overview of the project is as follows. First, during the Problem Discovery stage, the students learned of the necessity of promoting reading for children with the OECD Programme for International Student Assessment (PISA 2006 and PISA 2009), and selected "increasing children's reading understanding" as their project topic. During the Problem Clarification stage, they visited Nonoichi Municipal Library and investigated what books children were reading as part of the Nonoichi City project to encourage reading. Next, they made ideas about what kind of story and functions their picture book should have, and in the Idea Clarification stage they prototyped a book to be read to children. In order to test the efficacy of the prototype picture book, they gained the cooperation of the kindergarten and read the book to children there. After reading the book to the children, they asked for opinions from stakeholders. The kindergartners' response was positive, but the instructors were more critical, mentioning the possibility that the positive response was simply because the children liked new things, and that the story of the picture book should follow a clearer story pattern. Their activities at this kindergarten provided the students with external evaluation for their ideas, and the critical evaluation they received led to the next step in their project. Simply making the picture book in PD2 would only be up to the C-D aspects of CDIO (standard level for KIT's PD2), but by going to the kindergarten and receiving evaluation on their prototype picture book from a third party, they were able to make a "thing" closer to completion. Also, it functioned as an external evaluation system for receiving evaluation from experts (kindergarten teachers). An evaluation system such as this makes it possible to expand student projects from the C-D aspects of the CDIO approach to C-D-I. Also, by having an opportunity to read the book to children, the students were able to cover all aspects of C-D-I-O. If it was possible to have opportunities to read the picture book at other kindergartens and continue to improve it, it would lead to being able to read a picture book closer to completion.]

4.2. Evaluation of Engineering Design Process

In order to expand student projects from the C-D aspects of the CDIO approach to C-D-I and C-D-I-O, it is necessary not only that students make an active effort, but also that instructors can provide advice for each project and team, and run the class as a whole. Stakeholders for the topics the students are working on are also necessary, and instructors need to have the planning and implementation skills to connect student projects with these stakeholders. The above three examples were able to expand their projects to the C-D-I and C-D-I-O aspects of the CDIO approach because they had a clear grasp of user needs. In order to be able to present superior solutions, a common point in every team was the need to reconsider their ideas through prototyping.
Table 1 is an evaluation of the student projects mentioned above, using an evaluation index for engineering design process using the CDIO approach. The fact that each example received outside evaluation is good, but with a project length of 15 weeks it is difficult to have sufficient Operation, and there is a need to collaborate with internships or the like, as shown in Example 2.

Table 1. Evaluation of projects given as examples.

			An evaluation of the student projects	Example 1	Example 2	Example 3
C	Conceiving	1	Discovering problems	✓	✓	✓
		2	Clarifying problems (investigation of needs)	✓	✓	✓
		3	Creating design specifications	✓	✓	✓
D	Designing	4	Creating, evaluating, selecting ideas	✓	✓	✓
		5	Clarifying ideas	✓	✓	✓
		6	Creating planning and design documents	✓	✓	✓
I	Implementing	7	Negotiations, schedule proposal, progress management	✓	✓	✓
		8	Implementation of ideas	✓	✓	✓
		9	Confirming operation of product and self-evaluation	✓	✓	✓
O	Operating	10	Report on results	✓	✓	✓
		11	External evaluation of product	✓	✓	✓
		12	Proposal for improvements of product, improvements		✓	

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5. Conclusion

This paper used examples from PD1 and PD2 engineering design courses taught by the author in the past to describe the relation between KIT's engineering design process and CDIO. PD1 and PD2, which carry out projects following the engineering design process, already fulfill the C-D aspects of the CDIO approach. Also, in some cases they go as far as C-D-I or C-D-I-O. Since CDIO is an engineering education curriculum framework, it is not necessary to fulfill the CDIO guidelines with a single course. The different courses provided to students can be coordinated so that the curriculum as a whole fulfills the CDIO guidelines. However, expanding the content of PD1 and PD2, as core courses, would lead to improving the engineering education at KIT.

The engineering design process at KIT is made to develop problem-finding skills in the early stages, and problem-solving skills in the later stages. However, if a project moves forward without adequately grasping user needs, then there will be hesitation when moving from Idea Creation to Idea Clarification. In order to avoid this, it is necessary to prototype during the Idea Clarification stage, and reconsider whether the "thing" that is being presented is fulfilling user needs. This will lead to education that is balanced in problem-finding and problem-solving skills. If it is also possible to have stakeholders involved in examining the solution, then that can work as evaluation by a third party. By incorporating those opinions, it is possible to make a "thing" that is closer to completion. This can enable extending the quality of student projects to the C-D-I or C-D-I-O aspects of the CDIO approach. In order to do so, it is important to engage in even stronger collaboration with the community.

For craftsmanship in the 21st century, it is important to incorporate design methodology into craftsmanship, and create new added value for users of the "thing" [10]. In order to build a sustainable society, it is also important that craftsmanship is in harmony with the natural environment. Therefore, in order to train students to apply their knowledge to create new value, it is necessary for students to be aware of how their solution interacts with people at each stage of the engineering design process of the project. By doing so, students will be able to develop balanced problem-finding and problem-solving skills.

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Development of a Leadership Course through a Case Study Evaluation and an Analysis

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Abstract

To ensure that engineering students can be important leaders, the College of Engineering of Seoul National University has opened a leadership course called "Challenge of Engineering Students and Leadership" as part of the engineering curriculum. The objectives of this class are to motivate students to become passionate essential engineering leaders in the future and to introduce the career and engineering frontiers, which is expected to be important in the future. This class consists of two units. The first is entitled the "Leadership Unit," during which students can learn how to be true leaders, and the second is the "Challenge Unit," where students can be inspired to learn career paths engineering students may explore and current engineering frontiers unfolding. We were able to look back on our leadership training course, which we have run for two years. Through an in-depth analysis of lecture evaluations and interviews with students, we instituted an enhanced model to foster SNU students as global engineering leaders and sought ways to develop and cultivate true engineering leaders by implementing an improved course.

Keywords: *Engineering Leader, Case Study, Development of the Course, Evaluation and Analysis*

1. Introduction

Recently, given the rapid development of technology, the characteristics of leaders of modern industrial environments have changed. In addition, the demand for managers with an engineering background is increasing. Engineering leaders who possess expert skills and who are proficient in the area of management are more effective than those who lack such skills. For this reason, the ratio of CEOs with engineering backgrounds in Korean companies is increasing. According to the Herald Business newspaper (4th July, 2014), nearly half of CEOs in the top 1000 Korean enterprises had backgrounds in engineering. However, it is not always the case that all people who majored in engineering are qualified to be a CEO. They should also have many other abilities, such as engineering expertise, and analytic thinking and management capabilities.

To correspond with this social and current demand, the College of Engineering of Seoul National University continually strives to develop and operate a leadership curriculum. In this thesis, we introduce the preparation process of leadership training for engineering leaders who study at the College of Engineering of Seoul National University and suggest methods of improvement and proper directions for leadership training through an in-depth analysis involving several cases over the past two years. The outcome of this study is expected to contribute to the promotion of the engineering leaders required by society by providing various materials for the efficient management of the leadership curriculum.

2. Leadership Course

Definition of Leadership

Many scholars who have conducted studies on leadership have defined leadership in different ways. Choi Yun-mi (2008) defined leadership as the follows. First, leadership is a group phenomenon when there is a leader and followers in an organization. Second, the leader and followers cooperate with each other to achieve organizational goals. Third, the leader exerts influence over followers to accomplish common aims. Fourth, leadership can be handled by anyone, as it means responsibility, not a privileged position [1]. Jago (1982) defined leadership as the exercising of non-coercive influence to coordinate the members of an organized group to accomplishing the group's objectives. Leadership is also a set of priorities attributed to those who are perceived to use such influences successfully [2]. Therefore, leadership is the ability to have a positive influence on an organized group and to accomplish the group objectives by creating a synergic effect by coordinating with members of the group.

Preliminary considerations: Focusing on case studies of foreign universities

Several universities have developed various leadership education courses to train engineering leaders. A listing of leadership education courses we studied is shown in Table 1. In order to foster the engineering leaders required in the twenty-first century, the College of Engineering of Seoul National University presented its vision of five innovative educational directions and accordingly set specific educational goals shown in Table 2.

We developed this educational course given the requirement to incorporate the above educational vision and the concept of talent in undergraduate education. This process is shown in Figure 1. Offering this leadership course is expected to develop in students a broad understanding of industrial and societies, a sense of responsibility, and the qualities of a leader. Below we proceed with an analysis and evaluation through a case study of the leadership course.

Table 1. Leadership Programs of Several Foreign Universities

University	Program
Penn State University	Engineering Leadership Development Program
MIT	Gordon-MIT Engineering Leadership Program
University of Michigan's College of Engineering	Engineering Global Leaders Honors Program
Iowa State University's College of Engineering	Engineering Leadership Program

Table 2. Educational Goals of the College of Engineering of Seoul National University

Education goals of the College of Engineering
Education for an Engineering Leader
Education for a Community Member
Education to be a Leader of Industry and Society
Education to be a Proactive Leader
Education to be a Progressive Leader

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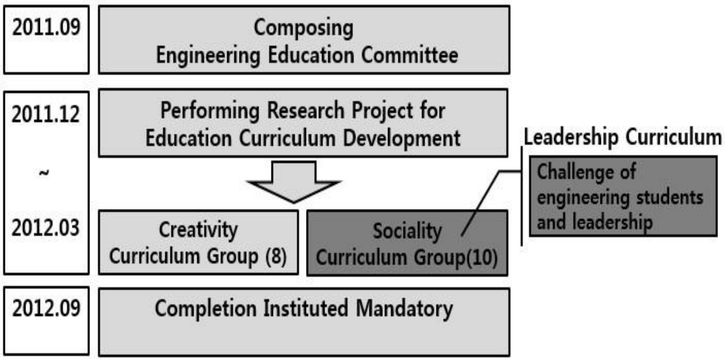

Figure 1. Development of the Leadership Education Curriculum

3. Analysis and Evaluation

Classes in the 'Challenge of Engineering Students and Leadership' program were offered during the spring semesters of 2013 and 2014. They were divided into 'leadership unit' and 'challenge unit: career and engineering and frontiers' with three credit hours in total, with each class lasting ninety minutes. Each single class consisted of lectures by experts in various areas. The leadership unit consisted of lectures which were intended to motivate participants to become engineering leaders, career frontiers introduced students to various career paths engineering students may explore, and engineering frontiers introduced students to evolving and converging engineering fields expected to be important in the future. Invited industry leaders from Samsung Electronics (2013) and Hyundai Motors (2014) gave lectures in practical leadership in industries, graduates of the College of Engineering of Seoul National University with successful careers in various fields such as industry, university, research organization, law, government, and international organization gave lectures about career prospectives for engineers, and professors at the school introduced students to upcoming promising areas of engineering [3].. Tables 3 and 4 shows contents of the course.

Table 3. Contents of the Course, Challenge of Engineering Students and Leadership (Spring Semester of 2013)

Leadership Unit*	Challenge Unit: Career and Engineering Frontiers	
	Lecture	Lecturer
Be a frontier leader	Engineering in art	UC Santa Barbara
Build your brand	IT fusion	[SNU] Electrical Engineering
Build your goal	Appropriate technology	[SNU] Chemical Engineering
Time management	Disaster prevention	[SNU] Aerospace Engineering
Communication skill	Environment	[SNU] Environmental Engineering
Care for others	Research careers	Korea Aerospace Research Institute
Be a global leader	Biomedical technology	[SNU] Technology Management Economics and Policy program
About Samsung Electronics	Government careers	Ministry of Education
Practical leadershipin R&D: Semiconductor	Industry careers	Samsung Electronics IP
Practical leadershipin R&D: Optical systems	Energy	[SNU] Energy and Resource Engineering
Practical leadershipin R&D: Fluid design	Big data	[SNU] Industrial Engineering
Practical leadershipin R&D: Semiconductor equipment	Startup careers	Umzikim CEO
Practical leadershipin R&D: Display technology	Law careers	Samsung Electronics IP

* Lecturers from Samsung Electronics

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Leadership Unit		Challenge Unit: Career and Engineering Frontiers	
Lectures		Lectures	
Be a frontier leader		Art engineering	UC Santa Barbara
Build your brand		IT fusion	[SNU] Electrical Engineering
Build your goal		ODA	[SNU] Chemical Engineering
Time matters		Disaster prevention	[SNU] Aerospace Engineering
Communication skill		Environment	[SNU] Environmental Engineering
Care for others		Energy	[SNU] Technology Management Economics
Be a global leader		Biomedical technology	and Policy program
About Samsung Electronics	Samsung Electronics	Big data	[SNU] Industrial Engineering
Semiconductor		Government careers	Ministry of Education
Optical systems		Industry careers	Samsung Electronics
Fluid design		Research careers	[SNU] Mechanical Engineering
Semiconductor equipment		Startup careers	Umzikim CEO
Display technology		Law careers	Samsung Electronics IP

Table 4. Contents of the Course, Challenge of Engineering Students and Leadership (Spring Semester of 2014)

Leadership Unit & Engineering Frontiers		Challenge Unit: Career and Engineering Frontiers	
Lecture	Lecturer	Lecture	Lecturer
Life as an engineer in Hyundai Motors		Professorships	[SNU] Electrical Engineering
Predicting the future		Government careers	Ministry of Education
Comprehensive thinking		Consulting careers	Consulting company
Engineering expertise	Lecturers from Hyundai Motors	Industry careers: Domestic	LG Electronics
Leading changes		IT fusion	[SNU] Electrical Engineering
Devotion and indulgence		Research careers	Korea Institute of Machinery & Materials
Communication		Law career	Samsung Electronics IP
Leadership & followership		Industry careers: International	Paradise Group
Megastructures	[SNU] Environmental Engineering	Big data	KAIST
Environmental engineering	[SNU] Chemical and Biology Engineering	Summary: Engineering Careers	CEO of Norupaint
Energy	[SNU] Energy and Resource Engineering	International organization careers	IAEA
Nano & materials technology	[SNU] Materials Science Engineering	Startup careers	[SNU] Electrical Engineering
Art engineering	[SNU] Electrical Engineering	Biomedical technology	[SNU] College of Medicine

Leadership Units		Engineering and Career Frontier Units	
Lectures		Lectures	
About Hyundai Motors	Hyundai Motors	Professorships	[SNU] Electrical engineering
Predicting the future		Government careers	Ministry of Education
Practical works		About consulting	Consulting company
Responsibility		IT fusion	[SNU] Electrical Engineering
Customer satisfaction		Research careers	Researchers
Be a R&D leader		Law career	Samsung Electronics IP
Megastructures	[SNU] Environmental Engineering	Industry careers	LG Electronics
Environmental engineering	[SNU] Chemical and Biology Engineering	Big data	KAIST
Energy	[SNU] Energy resource Engineering	International organization	IAEA
Nano & materials technology	[SNU] Materials Science Engineering	Foundation careers	[SNU] Mechanical Engineering
Art engineering	[SNU] Electrical Engineering	Biomedical technology	[SNU] College of Medicine

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Data collection and analysis methods

We derived the proposed enhancements by carrying out course evaluations and focus group interviews. Participants completed course evaluations in 2013 and 2014. At the end of the courses, students completed the course evaluations through an online course evaluation system which consisted of basic questions (centering on necessity of the education and the appropriateness of the content) and subjective questions (comments from students). There were 119 respondents in total (53 students in 2013 and 66 students in 2014) and 110 freely described subjective responses (40 such answers in 2013 and 70 answers in 2014). Questions concerning the necessity of the education and the appropriateness of the content are shown in Table 5. There were six objective questions. The participants' freely described comments about the courses including their impressions and suggestions for improvements.

Table 5. Course Evaluation - Necessity of the Education and Appropriateness of the Content

Question No.	Course evaluation - necessity of the education and appropriateness of the content
1	Do you think that the leadership training content was appropriate and beneficial?
2	Do you think that the engineering frontier training content was appropriate and beneficial?
3	Do you think that the career frontier training content was appropriate and beneficial?
4	Do you think that leadership training is necessary?
5	Do you think that engineering frontier training is necessary?
6	Do you think that career frontier training is necessary?

Results

1) Course evaluation - necessity of the education and appropriateness of the content

Most students were satisfied with the lectures and strongly supported their necessity (Figure 2).

2) Course evaluation - participants' free comments

We asked students to add open-ended responses in an effort to determine their level of satisfaction with the 'Challenge of Engineering Students and Leadership' program but also to find additional content for this training course. We needed to consider this in order to improve the course through the suggestions offered by the studentsl. The concerns expressed in the comments on the course included lecturer issues, the low participation rate of the students, and the limited diversity of lecture topics.

3) Lecturer-related issues

The students reported that there was an excess of business-related information and promotional content, and they eanted young working-level staff or young lecturers related to start-ups. They suggested that we invite well-known professionals in certain areas instead of a person from a company (Figure 3).

4) Student attitude and class participation

Due to the absence of a rigorous evaluation system in the course, the students were not fully absorbed in the classes. Therefore, we suggest a system that motivates students to participate, such as quizzes, discussions and other methods.

5) Topics in diverse areas

Many students reported that they hoped to listen to lectures in as many areas as possible in diverse specialties or from representatives of invited companies. Introducing enterprise management cases and the organizational cultures of various industries rather than major companies could augment and broaden the leadership education program. Furthermore, students suggested the need for lectures related to finance, law and consulting. One requirement of leaders with experience in business administration past a certain point is a 'cross-function', which is important to derive synergies through collaborations with those in non-engineering fields (Figure 4).

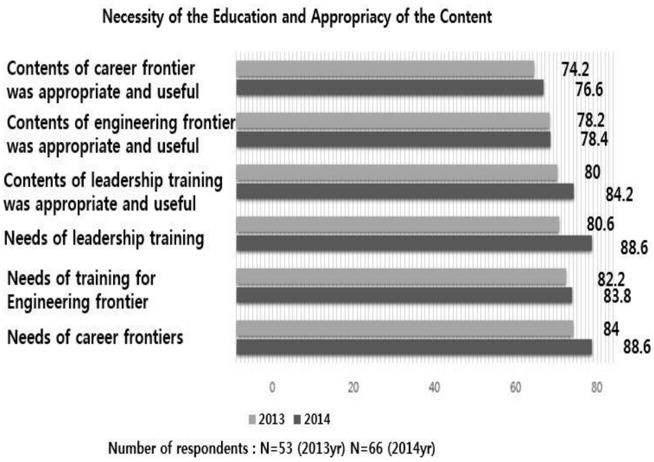

Figure 2. Course evaluation: Necessity of the education and appropriateness of the content

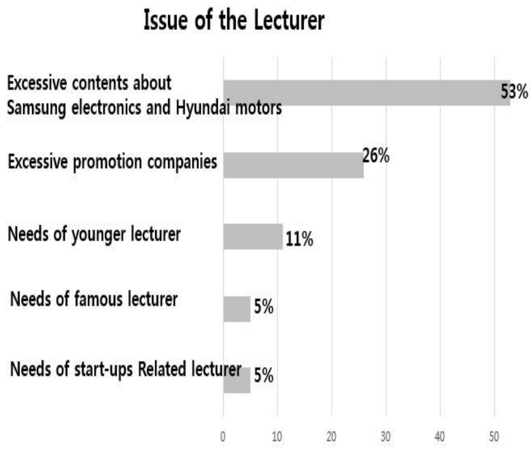

Figure 3. Issues related to the lecturer

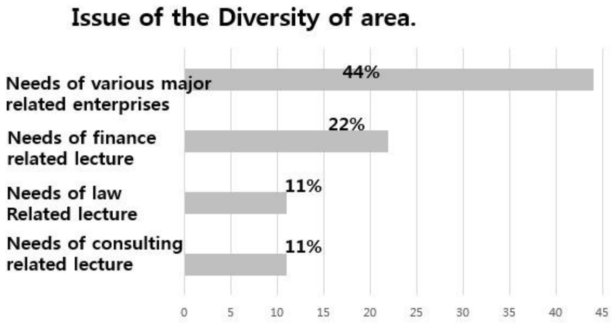

Figure 4. Issue related to the diversity of the area

The main purpose of this study is to uncover potential improvements in the leadership course by analyzing the results of course evaluations of the 'Challenge of Engineering Students and Leadership' program. Data were collected qualitatively, and the results are summarized in Figure 5.

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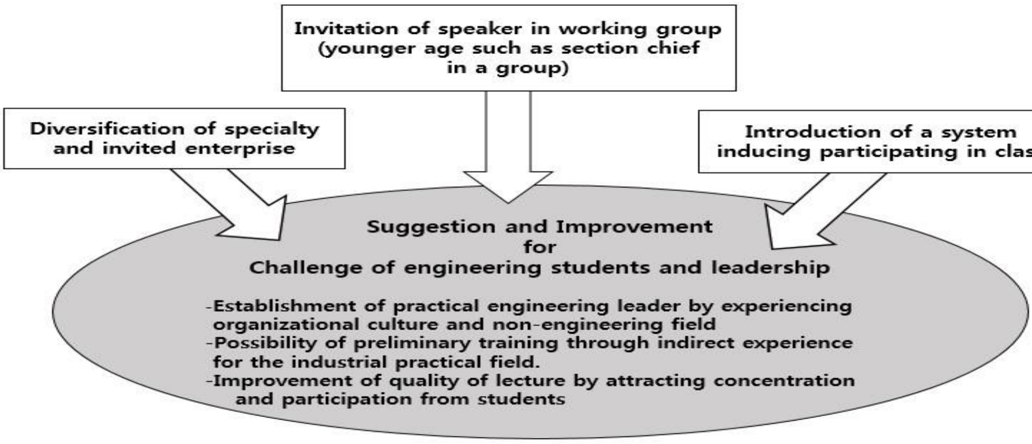

Figure 5. Suggestions and improvements for the Challenge of Engineering Students and Leadership program

4. Conclusion

One requirement of the twenty-first century is not simple managers of organizations but leaders who offer new prospects for organizations and achieve excellence in their goals with synergistic effects by cooperating with others. If the suggested educational directions from the discussion can be reflected in the curriculum and improve the leadership education at engineering colleges through the full utilization of these suggestions, it is expected that technical engineers can serve as global leaders who will accomplish their goals effectively.

First, in order to perform the role of a leader of an organization, engineers must have professional knowledge as well as an open mind to those in non-engineering fields. Providing special lectures by more diverse enterprises can help students understand practical engineer leadership roles. Moreover, by providing various lectures covering other areas, such as law and finance, students can learn related knowledge and gain indirect experience in advance. Therefore, they can improve themselves and cultivate cross-functional abilities. Second, if we lower the average age of lecturers rather offering lectures by existing company executives, it will be possible to relate stories about practical fields to engineering students. Third, for each lecture, each new lecturer gave different lectures. For this reason, the students were not fully absorbed in the classes. Therefore, the students suggested inducing a regular test system, such as quizzes and discussion-based tests. This can give consistency and a positive ambiance to the course through regular control and can increase the participants' concentration. Moreover, the efficacy of the delivered lectures will increase.

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