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198 SUPPORTING PROGRAMME DEVELOPMENT WITH SELF- AND CROSS-EVALUATIONS – RESULTS FROM AN INTERNATIONAL QUALITY ASSURANCE PROJECT

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ABSTRACT

This paper introduces the results from an international quality assurance project 'Quality Assurance in Higher Education Institutes II'. The main goals of the project were to further develop and disseminate the quality assurance methods and tools defined in the first project. The project had six partner universities from five different countries. The project started in summer 2011 and continues until September 2012. The project had three main phases: workshops, self-evaluation, and cross-evaluation. The workshops were supporting pedagogical development, quality assurance and evaluation phases in partner universities. The self-evaluation of the degree programmes described the programs, defined areas of further improvements and provided basis for the cross-evaluations. As a result of the project, new tools and methods of quality assurance were adopted in partnering universities. In addition, the international co-operation in quality assurance and curriculum development was deepened. Finally, the evaluated programmes received direct feedback from the cross-evaluators for their near future development actions.

Keywords: Quality Assurance, CDIO, Self-evaluation, Cross evaluation, Program development, Continuous development.

1 INTRODUCTION

In the field of higher education, international co-operation and comparability of education as well as quality assurance are challenging higher education institutions (HEIs) to find new solutions to monitor and improve the quality of teaching and learning [1-4]. In order to educate the future professionals to meet the competence requirements of working life, the quality assurance processes in higher education needs to be developed further. For example, a survey among teaching professionals in higher education institutions in over 30 European countries reported that a large majority of respondents acknowledged the need for European quality standards for higher education [5]. Already the Bologna declaration stated that European co-operation in quality assurance should be promoted [6]. The Quality Assurance in Higher Education Institutes I [7, 8] and II projects are answers to these challenges and requirements. The QA in HEI projects responds also to the ENQA-report [9] where a widely shared set of underpinning values, expectations and good practice in relation to quality and its assurance were called.

The CDIO initiative [10], offering an ideal framework for curriculum development and outcome-based assessment, emphasizes also the importance of quality assurance work in HEIs. The CDIO initiative is an innovative educational framework and international collaboration network of engineering educators. The CDIO initiative is built on the 12 CDIO standards [11] and CDIO syllabus. The standards act as guiding principles for design and development of a degree programme. Focusing the development in the areas defined by the standards will lead to better student experience and improved learning results. The 12th standard sets the principle of quality assurance and continuous improvement to the development of a degree programme.

In this paper, we will show how six universities in Northern Europe have worked together to strengthen the quality assurance procedures in their institutes. First we introduce the Quality Assurance in Higher Education Institutes II project. After that the project results will be introduced. Finally, we will discuss our experiences and give conclusions.

2 QUALITY ASSURANCE IN HIGHER EDUCATION INSTITUTES II PROJECT

The Quality Assurance in Higher Education Institutes (QA in HEI) II project continues the work done in the first QA in HEI project [7, 8]. In the first QA in HEI project a new self-evaluation model and a new cross-evaluation model was developed and successfully tested. During the first QA in HEI project, knowledge of the CDIO initiative as a framework for quality assurance increased too although the partners have been in close cooperation since 2007 in the CDIO network.

This new QA in HEI II project started in 2011 and continues until September 2012. The purpose of the project proposal is to enlarge the Nordic network of the previous project (Turku University of Applied Sciences and Helsinki Metropolia University of Applied Sciences from Finland, Royal Institute of Technology from Sweden and Technical University of Denmark) with new partners from Baltic countries: University of Tartu from Estonia and Vilniaus University of Applied Sciences from Lithuania. In the QA in HEI II project, the self-evaluation model will be introduced to new programmes and implemented to identify development areas in the curriculum of selected degree programs. Furthermore, the applicability of the self-evaluation model will be tested in a different higher education environment and developed further in a larger Nordic-Baltic network. By introducing a new framework of quality assurance in Baltic partner universities, project also contributes to the comparability of educational quality of HEIs in international level. Cross-evaluation model, developed also in the QA in HEI-project, promotes both self-assessment and international comparability of educational quality. In Nordic-Baltic level, the project aims at strengthening the co-operation of HEIs in quality assurance of engineering education and to disseminate best practices of quality assurance working methods and educational solutions between HEIs.

The main goal of the project is to disseminate the quality assurance methods and tools developed in Quality Assurance in Higher Education Institutes–project (2010-2011) to new partner universities from Baltic countries and to new programmes in the old partners. In this follow-on project the Nordic partners will act as mentors by guiding new partners through the quality assurance process and familiarizing them with CDIO framework which provides the methodological basis for educational quality assurance. By offering new innovative models and tools, the project promotes the quality assurance work and continuous curriculum development in the field of engineering science in Baltic partner universities, strengthens their commitment to the CDIO framework and the cooperation between Nordic and Baltic partners.

Project had three main phases: 1) Workshops, 2) Self-evaluations and 3) Cross-evaluations. The idea of workshops was to support the evaluation process in programmes that were new to the CDIO initiative and the QA process developed in the first QA in HEI project. The evaluation process had five steps (Table 1).

TABLE 1. Evaluation steps and outcomes.

Steps	*Outcomes*
Create the programme description	- Programme description with necessary appendixes
Make the self-evaluation	- CDIO self-evaluation report - Description of three best practices - Description of the local self-evaluation process
Time for improvement and development	- Action Plan showing the defined and scheduled development step
Preparing for cross-evaluations	- A report of the most important measures that have been implemented since the self-evaluation
Cross-wise evaluations	- The cross-wise evaluation report - A description of the cross-wise evaluation process (and possible suggestions for improvement of the process)

Each partnering HEI performs a self-evaluation process in degree programmes that are selected for this purpose. The self-evaluation process is conducted by following the previously defined self-evaluation process steps [7]. The self-evaluation process is followed by cross-evaluation that is performed pair-wise, pairs consisting of one Baltic and one Nordic partner. The pairs of cross-evaluation are selected by the participating degree programmes and experts from each HEI. The degree programmes are paired off based on the disciplines and the evaluation process is performed again by the cross-evaluator. In order to promote international comparability of education, the cross-evaluation pairs represent different nationalities. The cross evaluation will follow the model developed in earlier QA in HEI project as well. The evaluation will respect the principles of appreciative evaluation. After the cross-evaluation, the results of the evaluation are reported to the evaluation partners. Based on the evaluation report results, the degree programmes refine the feedback to development plans, which define the precise actions for improving the quality of education. Accordingly, the HEIs prepare a development plan that describes the actions that are aimed at improving the educational quality in institutional level.

3 PROJECT PHASES AND RESULTS

3.1 Workshops

The project organized three workshops in pedagogical development and quality assurance:

- Pedagogical CDIO workshop I, 23.11.2011, Tartu
- Self-evaluation and QA workshop, 12.12.2011, Vilnius
- Pedagogical CDIO workshop II, 11.4.2012, Vilnius.

The workshops were defined to provide support for the pedagogical development and quality assurance work. The workshops were delivered by representatives of two project partners: Turku University of Applied Sciences and Royal Institute of Technology. Each workshop had around 15-20 participants. The participants were mainly from the hosting institute but some participants joined from the other project partner institutes as well. The pedagogical workshops contained topics such as CDIO initiative, project-based learning, integrated learning and engaging students in their learning. The quality assurance workshop focused on CDIO standards and the self-evaluation process. Especial focus was on the standard 12 (Program Evaluation), which describes the ideology of self-evaluation.

3.2 Self-evaluations

Four degree programmes (Table 2) joined the self-evaluation process which involved detailed program description and self-evaluation with CDIO tools.

TABLE 2. Degree Programmes in evaluation process.

Degree Programme	*Institute*
Information Technology	Turku University of Applied Sciences
Software Engineering	Vilnius University of Applied Sciences
Electronics	Helsinki Metropolia University of Applied Sciences
Computer Engineering	University of Tartu

While Royal Institute of Technology and Technical University of Denmark did not have any programmes in evaluation phases their role was to be external observers of the evaluation process. The self-evaluation process of each HEI had some differences, but in each HEI faculty members, students and industry representatives had some role in the evaluation process. The main development actions identified in self-evaluations are shown in the Table 3.

TABLE 3. Identified development actions.

Programme	*Development actions*
Electronics (Helsinki)	- Outcomes need to be processed more - More integration needed to engineering - Faculty co-operation in integrated learning experiences should be improved - More training on active learning - Course assessment will be improved in curriculum process - Need for project facilities - Actions based on the feedback
Computer Engineering (Tartu)	- Use of collected feedback data should be improved - Connection with working life and real engineers
Information Technology (Turku)	- Learning outcomes require updating and consistency with the program goals - Assessment of Integrated learning experiences in lab courses - Introductory design build project is needed - More flexible space is needed - Engage students more in the programme development - More projects and working life connections
Software Engineering (Vilnius)	- Start student participation in program renewal process - Design programmes based on competences and learning outcomes - Improve QA practices with self-evaluation

3.3. Cross-evaluations

In cross-evaluation phase four pair-wise cross-evaluations were done. The cross-evaluations based on the self-evaluation reports and site visits in Tartu, Vilnius, Turku and Helsinki belonged to the process. The site visit focused on program presentation, best practices, workspaces, questions and reflections from evaluators. The observators' feedbacks from the cross-evaluations are listed in the Table 4.

TABLE 4. Observations from the cross-evaluations.

Programme	*Impressive experiences and strengths*	*Challenges and open questions*
Computer Engineering (Tartu)	**Impressive experiences** - feedback system; forces the students to give feedback of a number of courses per semester - electronics labs open 24/7 - programme evaluation on consistent basis - the attitude of the programme management to pedagogical development **Strengths** - teacher to teacher –seminars; even though limited attendance - capstone and first year projects - Introduction to specialty; should it however be compulsory? - the use of student assistants	**Challenges** - mass courses in mathematics and physics; low level of integration to - professional studies - RDI activities strongly emphasized over teaching among the staff - lack of compulsory industrial work placement during the studies - level of international exchange **Open questions** - formal implementation level and knowledge of CDIO - the level of e-learning - employability of the graduates in Tartu region - level of industry cooperation; both in capstone and final year projects

TABLE 4. continues.

Programme	*Impressive experiences and strengths*	*Challenges and open questions*
Software Engineering (Vilnius)	**Impressive experiences** - Active Working life connections: projects; teachers from industry; reaction to changes in the environment - The procedure to design the curriculum: representatives from industry, students, …; background research - Course documentation seems to be very informative - The overall accreditation procedure **Strengths** - Final practice usually leads to final project - The curriculum is "accredited" – freedom to change up to 25 % - Keeping up the study group together - International activities - The new e-business program uses CDIO principles quite well - Good employment figures - Quite small groups sizes in labs	**Challenges** - If you don't pass courses →drop-out - No flexibility with the compulsory courses - Supporting teachers in the change process - Connecting CDIO self-evaluations to strategic and operational planning - How to support individual study paths? How to avoid course chain problems (prerequisites)? - Changing teaching requires changes in assessment **Open questions** - Fee system seems to be complicated, but maybe also motivating - How to support students in their studies – relying on individual teachers' activity - Managing the large amount of part-time teachers? - What is the CDIO implementation plan and the next steps to be taken? - Initiating learning and practicing skills in students groups – students clubs?
Information Technology (Turku)	**Impressive experiences** - Innovation project consolidating different study programs - Easy process of curriculum update - Ability to obtain professional certificates during studies - Awesome Cisco laboratory - Working practice already in the 1st year - Dedicated space for students projects - Perfectly suited premises **Strenghts** - High flexibility of study program - Opportunities to participate in real IT projects during studies - All lecturers have pedagogical education - Feedback information from students and industry is used for curriculum development - Free of charge education - System for plagiarism detection - "Girls and technology" marketing activities	**Challenges and open questions** - Lack of strong motivation for repeated exams - Development of Alumni - Collection of more detailed student career information - Use of second (alternative) technology in some courses

TABLE 4. continues.

Programme	*Impressive experiences and strengths*	*Challenges and open questions*
Electronics (Helsinki)	**Impressive experiences** - The structure of first year studies (including first year engineering project and Introduction to Studies) - Small groups of 40 students - Teachers can enter custom questions to the feedback system **Strengths** - Spacious labs as curricular learning environment - Hands-on labs early in the program (and fuzzy problems) - Twice a year feedback meetings with student representatives - Mandatory 60-credit teacher training - Industry-driven projects - Systematic approach to mapping programme learning objectives with course outcomes	**Challenges** - How to facilitate independent/group study on school premises? - How to get students to give feedback on courses? - If first year project is moved to 1st semester and implements LEGO, how to preserve current engineering content as design-implement project in year 1? - To have labs accessible for students during weekends? - Continuous faculty development after the initial 60 credits - Getting industry involved in programme development and validation of learning objectives **Open questions** - Are teachers motivated/guided to use the feedback system? - There are several managers for this programme, yet their independent roles are somewhat unclear. - After mapping programme outcomes with course outcomes, what is the plan of utilizing these results? - Actual attitude of the staff towards CDIO?

As the cross-evaluation teams were familiar with the self-evaluation documents prior to the site visits, they could produce a short one-page executive report already at the end of the site visit. In this way, the reporting process became very compact and time-efficient. The evaluated programme analyzed the feedback carefully and made necessary additions and corrections to their own analysis.

4 DISCUSSION

The project reached well the original goals set in the project plan:

- The quality assurance processes in partnering programmes has improved with the implementation of the evaluation process
- Development of the programmes benefited from benchmarking self-evaluation results, best practices and cross-evaluations
- The continuous improvement process with CDIO initiative started/strengthened in the programmes
- The cross-evaluation process fostered co-operation between HEIs in the field of quality assurance work
- The educational quality, comparability and co-operation was promoted among the partner HEIs

- The practices of quality assurance methods applied in the project were shared and disseminated to new HEIs and new programs.

It proved very valuable design that cross-evaluators were from similar programmes. It was easy to find a common language and to go deeper into the program challenges. The international pairing made the evaluation process quite open – we are not competitors rather partner universities trying to help each other in the programme development. The external evaluators provided immediate feedback to programmes. They could also point out areas that were not acknowledged important in the programme earlier.

5 CONCLUSIONS

As result of the project, new tools and methods of quality assurance were adopted in partnering universities. In addition, the international co-operation in the area of quality assurance and curriculum development was deepened. The evaluation process has been successfully tested in two international projects and we can truly recommend this process to new programmes and universities.

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200 DEVELOPMENT OF AN ARTIFICIAL INTELLIGENCE PROGRAMMING COURSE AND UNITY3D BASED FRAMEWORK TO MOTIVATE LEARNING IN ARTISTIC MINDED STUDENTS

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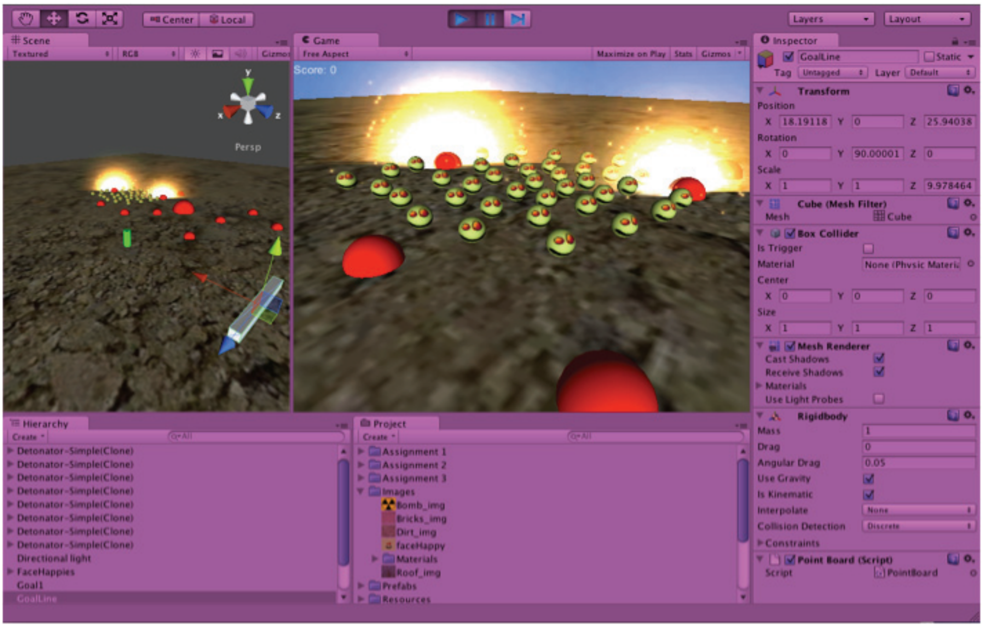

ABSTRACT

The paper aims at one of the problems many of the new multidisciplinary engineering educations encountered when teaching technical topics to students who are neither technically skilled nor aspired to learn these. The research continues and extends a study that has been done over a period of five years and tested on over 400 students at the bachelor part of the relatively new multidisciplinary engineering education Medialogy at Aalborg University Copenhagen. The author successfully found a number of pedagogical approaches for teaching technical topics to the challenging diverse students. The gap between technical and artistic minded students is, however, increased once the students reach the sixth semester. The complex algorithms of the artificial intelligence course seemed to demotivate the artistic minded students even before the course began. This paper will present the extensive changes made to the sixth semester artificial intelligence programming course, in order to provide a highly motivating direct visual feedback, and thereby remove the steep initial learning curve for artistic minded students. The framework was developed with close dialog to both the game industry and experienced master students, so the contend directly links to the demands of the students future challenges.

Keywords: Artificial Intelligence, Learning, Motivation, Multidisciplinary Education, Artistic Minded, Unity3D.

1 INTRODUCTION

The paper aims at one of the problems encountered when teaching students at a multidisciplinary education with diverse capabilities and even more diverse areas of interest. Medialogy Copenhagen is a relatively new education under Aalborg University Copenhagen. The education was initiated almost ten years ago to meet the growing demands from the industry to find engineers with a deeper understanding of humanistic and artistic competences in the fields of new media. The medialogiests are intended to possess capabilities in both development of new technical hardware and interfaces, as well as, contend for the new media platforms. New engineers should have an understanding of both the human cognitive response to media input, and an artistic understanding enabling them to engage in a discussion with, or be part of, any team creating the new trends in multimedia experiences.

After a few years it became evident that the type of students entering the education was not only the skilled hybrids between technical, humanistic, and artistic competences. Instead there was a large group of students solely interested in the creative humanistic and artistic fields. The education had therefore gradually lowered the technical expectations during the first 4-5 years. When the author of this paper was hired to teach the first two courses of programming, he became aware of the students weak technical skills, and requested permission to attempt to solve the problem by re-designing the way some of the technical courses were taught. By analyzing the students over several years while simultaneously introducing a range of changes in not only the concrete curriculum, but also in the fundamental way the problem should be perceived [1]. A fundamental change in the focus of the courses, the style of teaching, the form of exercises, and relation and merger with other courses did significantly improve both the skills and attitude, towards the technical courses, of the students in the second year of their bachelor.

1.1 Problem Based Learning

Aalborg University has since its creation in 1974 conducted all its educations by the principles of their own adapted style of problem based learning (PBL) [2,3]. Also the new multidisciplinary education of media & technology (Medialogy) follows these principles [4]. The students are therefore using approximately half their study time on a semester group project and the other half on semester courses that support their projects, such as the programming courses. The semester projects are fully managed and run by the students. The students will find a problem within the theme of the semester, analyze it, develop a product, and test it to find a conclusion to their problem. Because the students are working in self managed groups where sub-problems of both technical and artistic nature have to be solved. It is common that students follow their interest, and divide tasks based on individual strong skills to achieve the best solution at the end of the semester. Instead of focusing on balancing their skills and strengthen weak areas, as they should do. As a result of this, the gap between the strongest and weakest technical students grows all the way to their sixth and final semester of the bachelor. The artistic minded students are often those that have the weakest technical skills once they reach the sixth semester. As a result, this group of students are almost giving up on achieving a good result from, the algorithm and programming heavy, artificial intelligence programming (AIP) course, that ends their four semester long programming part of the education.

The attempted solution, to motivate the artistic minded students to engage fully in the AIP course, which is presented in this paper, is heavily based on the successful methods used to motivate them in their third semester programming course.

1.2 Programming at Medialogy

The Medialogy education has since the beginning had a four semester programming part, running from the third to the sixth semester. In the last six years the programming language of choice has been C/C++. The reason being not only that it has been the most used language for decades. Also, because it is a good language to work with, and most of their future employers ask for skills in this language. The language is introduced on the students third semester, as a procedural C/C++ course. The fourth semester is object oriented programming in C++. The fifth semester is OpenGL 3D graphics programming in C/C++. Finally, the sixth semester is the artificial intelligence programming course. Here C++ have been used since the students should at this point be very familiar with it. The sixth semester course has always been an introduction to artificial intelligence. It has for several years included topics such as: Physics, graphs, path finding, finite state machines, and decision trees.

2 METHODS

After a few years of analyzing the students in connection with the third semester programming course [1], it became evident that a large group of the students completely lacked any intrinsic motivation [5,6,7] to learn programming and other heavy technical courses, since they could not see these play any role in neither their future projects nor future jobs. Their strong passion for the artistic courses led them to put all their focus and energy in these. Many also convinced them self that no matter what they were told, then they would be able to complete the study by using all their time on becoming a digital artist. Programming was just something they needed to study a week or two before the exams to pass the semester and move on to the succeeding semesters promising artistic lectures. This is of course not the case, and many have to drop out after completing half the education. The extrinsic motivating factors are clearly not strong enough. Recent research by Daniel H. Pink [8] and others shows that a strong extrinsic motivation might not be only inefficient. But directly counter productive to solving problems that require creative thinking. One of the important goals was therefore to find means to improve the students intrinsic motivation to learn.

One of the initiatives improving the motivation on the third semester was a merger between the programming, image processing, and the semester project to give the students direct visual feedback for their exercises. This successful approach had naturally also been adopted by the sixth semester AIP course. This was done, by asking the students to use their new learned skills in OpenGL 3D-graphics programming to visualize the algorithms of the AIP course.

Unfortunately, OpenGL programming was not the biggest success among the artistic minded students. So they ended up using endless hours trying to visualize the first couple of exercises, after which they would again loose motivation for the course.

2.1 Using Unity3D

Since the big breakthrough of the Unity3D graphics engine, it has become increasingly popular among the students. The greatest reason for the success of Unity3D is the ease of use. Already in the first versions of the Unity3D engine the goal was to enable 'everyone' to make 3D games and experiences. The engine is today one of the most used in the industry, and the students know that they will likely be working in Unity3D if they dream of a career making games or related experiences. Most students are therefore using Unity3D for the sixth, and sometimes fifth, semester projects. The author therefore decided to rethink the AIP course in relation to the possibilities of Unity3D as a supporting tool for teaching. The course had to appeal to both the strong technical as well as artistic minded students. While challenging the programmers, the goal was to keep the artistic minded students motivated to work on their programming and A.I. skills.

On the assumption that none or very few of the artistic minded students had any prior experience developing in Unity3D, it was decided to develop a framework on top of Unity3Ds own. Reasoning that if the effort to get the first step working was as small as possible, then the success of actually controlling the engine, should give a boost of motivation for increasingly harder and more challenging problems. The framework had to be made in an easy transparent style so all students could reuse every done exercise in their semester project work, if so desired.

2.2 Designing the course and exercises

It can often be a challenge to keep the curriculum and exercises of a course on the cutting edge of what is moving in the industry. There is however only a few things as demotivating to students as knowing that the theory they are taught is obsolete and will never be used for any future project. On the other hand, teaching theory and methods that is new and revolutionizing on the forefront of innovation can be a great motivating factor in it self. Contacts to the industry, as well as relation to our own master students working with artificial intelligence was therefore used to decide upon what methods could be taught while remaining within the frame of the study-plan.

Another very important factor was that all elements of the course should work together, since the final exercise of the course was to combine all the learned material into one strong artificial intelligence. Ending the course in a highly hyped event where all students were allowed to bring and show a self-made artificial intelligent Unity3D challenger to meet the others in a tournament, designed to function as a long-term motivator. It did.

The framework was designed and build, to support the exercises of the course and to test if it indeed would improve the results of the course. In order to further reach out to the artistic minded students; the students were encouraged to replace all part of the framework graphics with their own models. One exercise was done in pure C++, another in OpenGL using C++.

This was done in order for the students to compare and give feedback on the Unity3D based framework. The following section will shortly describe the elements of the prototype framework used.

Finite State Machines (FSM) [9] are not only one of the easiest understandable artificial intelligence methods, it is also still one of the most used. The framework was build with a part to support a series of exercises in this field. Being able to build a simple A.I. controlled guard with a behavior similar to that of the NPCs in the famous MMORPG World of WarCraft, seemed an instant success.

Steering [10] is a series of methods enabling the A.I. to adjust to nearby obstacles or targets. The framework included a number elements and preset scenes to support a number of exercises in steering. Figure 1, shows a test-run in Unity3D where a large group of small 'happy' A.I. controlled balls have to chase a target in a landscape with obstacles. Any collision with obstacles or another 'face happy' results in instant explosions and destruction of the A.I.

Path-finding [9] was done in the more traditional way using OpenGL and C++. The student was here asked to simply take an old working program and adapt it to the exercises. A solution that should be easy for any student, with basic knowledge of C++ and OpenGL.

Behavior-trees [11] are one of the forefront techniques used in many of the AAA title games of 2011, and a new addition to the course. Because of the complexity of building a behavior-tree or simply building new elements to an excising setup, the framework included a design tool that enabled the students to design a number of behavior-trees using pre-made elements. Strong technical students could here decide to build their own behavior-tree elements without the framework, or using parts of the open code.

Decision-trees [12] also known as game trees, is again an old classic in artificial intelligence. The students where here asked to solve the exercises with nothing but pure C++.

The Battle Challenge offered the students to combine all learned methods in order to build an A.I. that would defeat all others in the search for glory and exclusive prices, such as some small board games, drawing tools, or a stack of Redbulls. The framework supported a setup where each student could bring a prefabricated (prefab) element for Unity3D. Each played would then control a castle, that could spawn numerous of the small explosive balls ('face happies') and steer them into the enemies castle. Path finding could be used in search for gold, and a fun mix of strategies tried to find the optimal way to bring the others' castles down.

3 RESULTS

The experiment is currently presented with three types of results. For each topic of the course, the students were asked to create a video describing how they had solved the series of exercises. These give a good indication of whether or not the framework was working as intended. A direct comparison is not possible since the workload from parallel courses varied greatly over the period of the course. Supporting the feedback stories from the videos, the author was in constant dialog with his students during or in between lectures. This giving a strong insight to the students state of mind during the course.

In order to evaluate the success of introducing Unity3D and the framework as the new teaching tool for the AIP course, an anonymous online questionnaire were build and linked to the students. Out of the approximately 30 active students exactly 24 answered the questionnaire (18 = male, 5 = female, 1 = ?). One of the big concerns before the beginning of the course, but also biggest goals, was that the students had to learn C#, Java, or Python in order to work in Unity3D; since it does not support C++. It was therefore expected that a large group might complain about having to learn a new language before they could start working on the artificial intelligence algorithms. But only 5 made that complaint. Instead the results show that almost as many students now feel they have good skills in C# as the number after three years feel they have good skills in C/C++. See Figure 2 below.

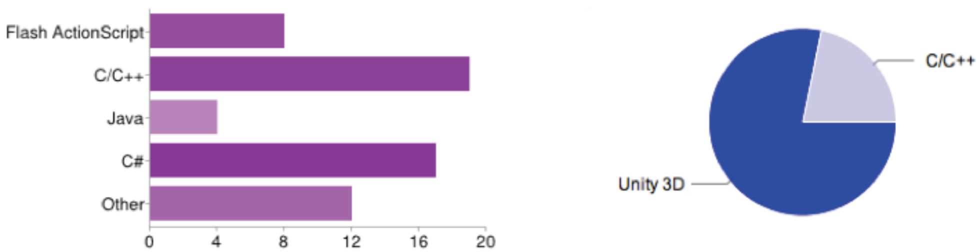

FIGURE 2. *(Left) "In which of the following languages do you feel you have good skills?". (Right) "Did you prefer the assignments in C++ or Unity3D?".*

The really interesting question is now. Did the change from OpenGL to Unity3D target and lift the group of artistic minded students in fear of falling out of the study so close to the end? The interaction and feedback given during the lectures and exercise time of the course, and the participation in handing in the exercise videos, showed that it did. Another clear indication can be seen in Figure 3. The group at the top of the left graph with no or little skills before the course is in fact the ones that have moved most in the last three months when looking at the top of the center graph. The improvement graph to the right show that some did not feel they improved much during the course. Looking at the data does however show that those feeling they did not improve much are mostly those that already feel close to expert level.

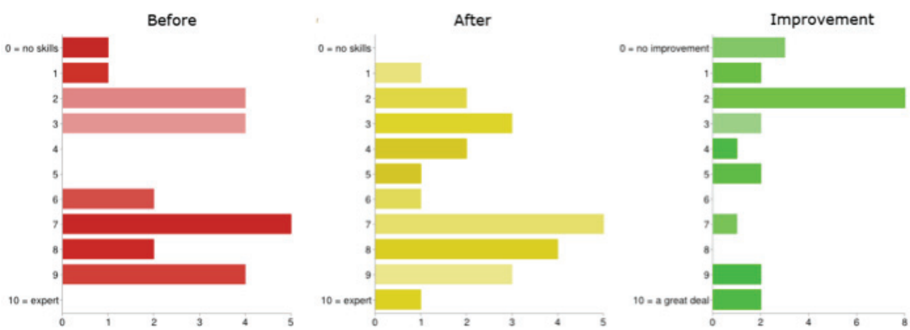

FIGURE 3. *(Left) "How would you rate your programming skills before the course?". (Center) "How would you rate your programming skills after the course?". (Right) "How would you rate your programming skill improvement this semester?".*

4 CONCLUSION

When the idea for this experiment was first presented to the study coordinator and study board to apply for permission to change the course I was sure it could work. I did however not expect the impact to be so clearly positive as it ended up being. The engagement and participation in the lectures, from the artistic group, have been significantly higher than the years before. I feel confident that the final exam in June will also clearly show that this group has learned more. The online questionnaire asked the students for two comments: "What is your primary field of interest?" and "What do you think about the use of Unity3D in the AIP course?". From those that did not write programmer in the first question, the second question received almost purely answers such as e.g.: "I think the intention of using Unity is brilliant, as this is the only course learning where we actually work with a game system (and in my opinion, the education is greatly lacking that element)". There was however also a great deal of the comments mentioning that they could feel it was the first time I was running the course using Unity3D. The few that preferred C/C++ also did it mostly because they liked working with a language they already knew. I hope my findings will inspire others to collaborate in solving the diversity problem of the many new multidisciplinary engineering educations.

6 ACKNOWLEDGEMENTS

Acknowledgement should be given to the many master students that through numerous casual discussions helped me understand what is useful and what is not. There should however be given a special thanks to Johnny Myhre, Kenneth Harder, and Kristian Klie from BetaDwarf for their kind technical help and advice to course curriculum.

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202 PROJECT-BASED LEARNING: THE SAE AERO DESIGN EXPERIENCE

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ABSTRACT

This paper describes some ongoing Project-based learning (PBL) experiences under development at the mechanical engineering course at the Federal University of Juiz de Fora, Brazil. Those experiences are related to student's team participation in the SAE Aero Design competition. The main argument is the great stimulus for the students that this kind of project can achieve. PBL principles consider the role of the teacher as a facilitator rather than a director of the process. In that sense, the students have to assume some tasks and roles that can bring to them experience and expertise that are not common place in the traditional disciplines and teaching and learning processes. These tasks and roles can be related to team organization and management, self learning, work division, among other with more technical content. The paper will present some theoretical background around PBL concepts and will report how students deal with difficulties and gains from the first experience of the team.

Keywords: Project-based learning, Aeronautical design, SAE Aero Design, Team organization

1 INTRODUCTION

1.1 What is Project-based learning

Project-based learning is a creative and highly effective means of teaching. Firstly, it should not be confused with Problem-based learning - both have the same abbreviation (PBL), and share some features. In this paper, we will refer to Project-based learning, and only, as PBL.

Both project or problem-based learning are ways to improve education processes, develop students' abilities and generate knowledge. They perform in constructivist guidance, leading each student in his own path to learning. It has been noticed that nowadays most students have some difficulty in solving long-term problems, which, however, exemplifies the majority of real situations - not easily solvable with mathematical formulas.

Quite often the difference between these two techniques is not clear, but some points should be considered. A common outset is some intriguing driving question or goal [1]. By exposing this, the teacher starts a chain reaction of thoughts in the class. Then the learners are encouraged to find one or more solutions to the hypothetical problem, aware that, in this case, teamwork should conduct to better results than individual. At this point, the role of the teacher is to facilitate rather than command the process, making the activities student-centered. From now on, the group or groups established should present an interesting and chiefly effective answer for the main request.

PBL approach has some particular features, which are usually not emphasized on Problem-based learning. Fundamentally, there has to be some definite output, either a real product or conceptual project. In second place, PBL is often a medium-term task, requiring extrinsic research and extra-class dedication by the students. Thus, each member of the team cultivates a personal connection to what is being constructed, making PBL a more attracting education method.

1.2 What is SAE Aero Design

Organized by SAE (Society of Automotive Engineers), Aero Design was created for engineering students interested in the aeronautical sector. The competition generates exchange of knowledge, techniques, aeronautical innovations among students and institutions. The student acquires much experience in aeronautic project, from its conceptual design, detailed development and design. Besides that, the team has to build an entire aircraft, following the rules determined by the responsible committee. Teams are formed by volunteer students to represent their institution, and each year a new regulation is made, with new limitations and objectives, so that students are challenged annually. SAE Aero Design competition is divided into three classes: Regular, Micro and Open, and each class have its particular rules. This project is divided in two moments, design competition and flight competition, where engineers in the aeronautical field evaluate the performance of the aircrafts.

Sometimes, for lack of knowledge, some people confuse Aero Design with aeromodelism, a hobby that deals with acrobatic and free flight aircrafts. The competition treated in this article consists of strict rules, knowledge in aeronautical engineering, structural, aerodynamic, etc., which are not strictly present in aeromodelism.

The first team to be founded at the Federal University of Juiz de Fora (UFJF) was the "Flying Mammoths", participant in the regular class, beginning operations in early 2010. Flying Mammoth prepared to compete in the year of 2011, the same year that Microraptor team was formed, to compete in micro class. Both groups had great support from UFJF, which provided machinery and some initial budget for lodging and transportation. The teams also had to pursuit external sponsorship, which was of great importance for the conclusion of the project.

2 HOW SAE AERO DESIGN EXPERIENCE FITS PBL

After setting up the main features of PBL and defining what SAE Aero Design is, it becomes necessary to match their corresponding aspects. Among many connections, we have chosen to focus on the following:

a) Student decision making without explicit teacher control. This is the foremost important concept involving PBL. In SAE Aero Design, each team is requested to project and built a radio-controlled aircraft to carry some cargo. As in a real aeronautical corporation, the project of an airplane requires many key decisions, which are to be made by one or more people from the staff. In our case, the conceptual, technical and team-managerial determinations are mainly in the hands of the students. Of course there are situations which demand some professor interference, but the development and management of the project and team are reserved to the undergraduates, who have to foster the habit of self-learning.

b) Teamwork, labour division and collaboration. As stated in 2011 SAE Aero Design regulation [2], one of the goals of the competition is "to develop the spirit of teamwork". A hard task in a student team is to designate the right person to the right field, which has to fit his knowledge and desire. In MicroRaptor team, the fundamental work division took into account five areas: Aerodynamics, Performance, Control and Stability, Structures, and computer-aided drafting (CAD). It is worth remembering that these areas are definitely related to each other, and reliable data and literature must be shared between them to secure a good quality project. Examples of each division are shown in Figures 1 to 3.

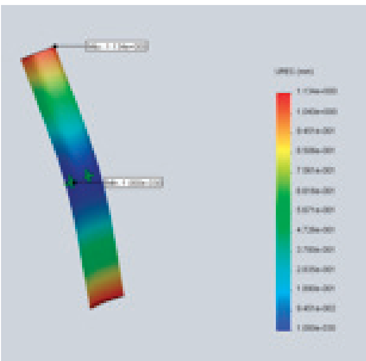

FIGURE 1. *Structural analysis software.*

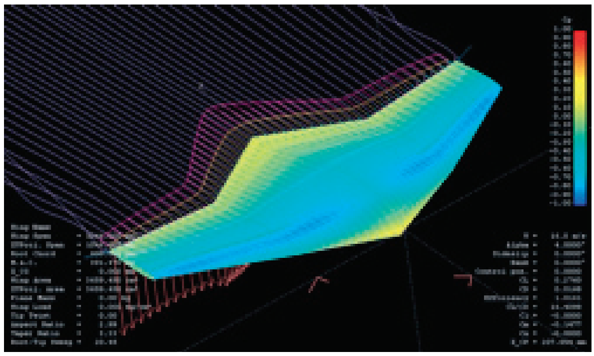

FIGURE 2. *Aerodynamics simulation.*

c) Scientific methodology for projects. Since a fully functional aircraft will be projected and manufactured, there are many levels of efficiency and effectiveness to accomplish these tasks. A scientific - or engineering - methodology helps by selecting the best path to follow. Two features should be highlighted:

PROJECT: Firstly, the students are presented to some basic literature appointing a few ways to start a project. This is the moment in which they discover that self-learning will guide them afterwards, indeed, for the rest of their lives. In UFJF Aero Design, the primary volume recommended was "Fundamentals of Aeronautical Engineering" [3], a book which instructs the composing of an aircraft project specifically for SAE Aero Design competition. Further reading was necessary to improve the technical section, and hence put the students in contact with some of the aeronautical engineering best-know authors. In this part the teacher is prone to interfere and implant his own ideas on the project. Nevertheless, this is the time when only trivial aid should be offered - as long as no critical failure is neglected.

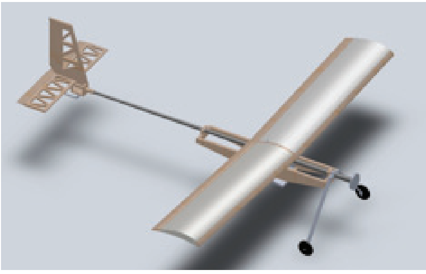

FIGURE 3. *Airplane modelled in CAD software.*

MANUFACTURE: During and specially after delivering the technical report to the committee, the team is encouraged to build at least two prototypes to ensure the feasibility expected from the theoretical model. Here starts the next step of PBL: the breeding of something which carries a direct connection to the real world engineering. To fabricate any aircraft, many tests and trial are required, in order to match the expected properties of the project.

Different materials were assessed for resistance (traction, compression and shear stress) and minimum weight, particularly important characteristics in an airplane. New ways of machining aircraft elements needed to be internally developed. Since aeromodelism often doesn't follow strict conformity to stringent projects, the team had to create its own ways of producing each component. For example, the wings in MicroRaptor were made of polystyrene (EPS) P3 (density tag). Its high resistance, relative to common EPS, as well as the precision needed to cut the airfoils, demanded an appropriate manner of dealing with, as shown in Figure 4.

FIGURE 4. *Manufacture of a wing.*

Another component that was subjected to tests was the engine-propeller system. In order to determine the best configuration of length and helical pitch, along with the lightest and most efficient electrical motor, several propellers and engines were attached to a weighing scale and the thrust for some input power was measured for some values (Figure 5). This procedure clearly resembles professional analysis present in real aeronautical industry. By this activity, the students become aware that any conclusion in the final project has to be made upon real and impartial observations and organized data.

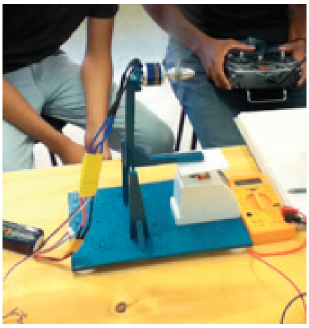

FIGURE 5. *Testing electrical engine and propeller.*

d) General planning and management. The best way to teach timetable organization and manipulation of human resources is to put some group in a real situation involving deadlines. PBL is explicit in this subject. In Aero Design, apart from some bureaucratic initial requirements, the main deadlines refer to the delivery of the technical report - showing detailed information about the project, including its blueprints - and subsequently some footage warranting that the plane taken to the competition has flew previously. Only a well-coordinated party is able to accomplish these marks with efficiency. There is no need to assert that any engineering corporation nowadays aims for employees acquainted to timetables and their particular responsibility in a supply chain. In MicroRaptor, the students were advised to appoint one of them to be responsible for the assembly of the final report, and another one to lead management issues, such as finances, patronage and public announcements.

e) Use of technology resources which wouldn't be used in "chalk and talk" classes. [4] shows that engineering education has been undergoing dramatic changes the last years. PBL takes part in this revolution, once it supports the suitable use of the latest technology to improve understanding. Aero Design project demands use of many resources, including virtual simulations, computer-aided engineering (CAE) and precise gauge devices for manufacturing tests. Those methods are not usually stressed in traditional classes, but are widely employed in PBL.

f) Troubleshooting and assessment of failures. A complete project depends intensely on continual evaluation of what is being done by the team. Human resources should receive special attention, since the group health relies on a well-coordinated management. Also the technical projects must be criticized constantly, in order to trim imminent failures. Tests are essential to solve potential trouble. Flights preceding the competition were encouraged, like the one shown in Figure 6, moments when the students were able to assess what could be improved in the next prototype to get more controllability, and what should be taken into account to prevent other crashes. Analysis of structural damage after mission simulations is also of great importance, and should be detailed in the technical report.

FIGURE 6. *First test flight.*

3 BENEFITS GAINED DUE TO PBL AERO DESIGN AT THE COLLEGE OF ENGINEERING OF UFJF

The SAE Aero Design competition is, above all, a technology generator work. To arrive at its final results (points in the competition) the team must go through several steps as mentioned before. Project's phases are assessed by researches on aeronautical engineering, fabrication processes, materials, aerodynamics etc. To apply this knowledge in the design of an aircraft, the student must formulate methods to prove theories.

The development of physical tests, structural analysis, aerodynamic project's method, material and electronica tests are mandatory for the project's success. Computation is an important tool to execute several numerical calculations. Much software is used by the team's members. It makes possible the realization of certain works and the speeding of processes that would be extremely troublesome without Informatics. The development of technology is visible when the students themselves create the software, using their knowledge of programming and calculus acquired at their respective classes. The team works on many programs that are used each year on new projects. These programs are real engineering tools.

The teams have many difficulties to make aerodynamics analysis due to the University's lack of resources or to the excessive specialization of this science. To overcome this problem, the students themselves try to formulate analysis' methods necessary to the project. A wind tunnel project made by the UFJF's students represents a search field creation for a project's problem solution.

Every material that is developed for SAE Aero Design competition, be it engineering tools or support projects, represents a technological gain to the UFJF's College of Engineering.

All projects that are based on learning, including SAE Aero Design, are an opportunity for the students to apply their classroom knowledge and to acquire professional skills. The SAE Aero Design project is a complete product design, from the concept formulation to the manufacture.

The student has the opportunity of taking part on a project that is similar to one made by a business.

SAE Aero Design project has in specific a character of technological renovation and actualization. The UFJF's College of Engineering intends to participate in the competition every year, always creating new technologies and renewing the team so that many students can participate and have the experience that helps them in their academic formation.

4 CONCLUSION

It became clear that PBL is a great means of teaching engineering, leading the students in an attractive and effective path to knowledge.

SAE Aero Design project is intrinsically related to learning, and figures in a classic example of PBL. 2011 competition in Brazil showed that there are many ways of providing students the expertise they need. It is important, however, that everyone involved in PBL knows what is being done and how it should be done. In this way, this teaching and learning technique can be of great convenience in engineering.

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204 DIDACTIC KIT FOR THE STUDY OF INTAKE AIR SYSTEM IN INTERNAL COMBUSTION ENGINE

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ABSTRACT

The development of vehicular embedded electronics allowed improving efficiency, conciliating fuel economy and gas emission. The intake air system in the internal combustion engine of Otto cycle is one of the most important and fundamental systems of the vehicle. The present investigation focuses on a didactic kit to study all the embedded electronics that controls the intake air system, using a set of sensors, such as MAP (Manifold Absolute Pressure), MAF (Mass Air Flow), TPS (Throttle Position Sensor), and the position of gas pedal. The project was developed with a decentralized architecture, in order to make the system more didactic. It consisted of two control modules: the turbine rotation and the intake air system management, with two microcontrollers providing a SPI (Serial Peripheral Interface) communication.

Keywords: Intake Air System, Engine Management, Throttle Body

1 INTRODUCTION

The present work describes a didactic kit that simulates the intake air system of an internal combustion engine with electronic injection. The main goal of embedded electronic systems to control engine combustion is to improve its efficiency, safety and comfort to users. Such didactic kit provides a good opportunity to students to explore this electronic control system [1].

Over the last few years, car production in Brazil increased substantially, reaching the 3 million cars produced per year [2]. On the other hand, training of automotive engineers has not followed such production pace, hindering further development of Brazilian car industry. In such shortage of engineers, the government of the state of Sao Paulo implemented a technology school in the Santo Andre city, a car industrial city. One of the major curricula of this school focuses on automotive technology and embedded electronics. This courseware contains elementary courses on circuit analysis, analogic and digital electronics, microcontrollers and control theory, along with some specific courses on engine management, automotive sensors and actuators, vehicular inspection, diagnostics, breaking systems, suspension and transmission systems, and controls of combustion engines. The development of this didactic kit intends to help in teaching activities of courses on microcontrollers and sensors and actuators, and lead students to experience the application of programming microcontrollers in automobiles, practical experience in sensors and actuators. In this sense, this set helps in teaching automotive electronics, an area that still lacks didactic tools.

2 BASIC CONCEPTS

2.1 Description of air admission system

Figure 1 shows the intake air system, where the fundamental elements are the throttle system and its electronic control. This system is coupled to a position sensor, which is essentially a potentiometer that indicates the opening angle, according to figure 2. The system also contains a MAP sensor, with pressure and temperature sensors, and in some cars, a mass air flow (MAF) sensor [3].

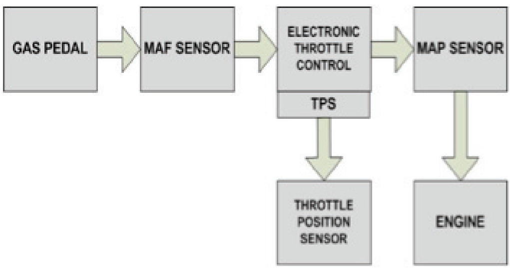

FIGURE 1. *Diagram of an air intake system.*

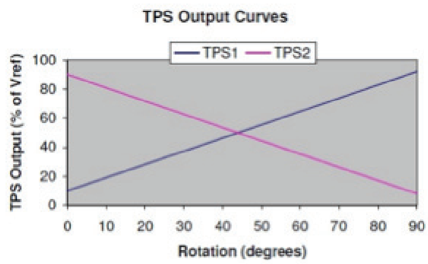

FIGURE 2. *TPS output curves (from [3]).*

2.2 Basic Operation

When the engine rotates from a starter or in conventional regime, it generates a depression in the throttle valve, decreasing the manifold intake pressure due to thrust that the engine cylinder has created and, consequently, creating a mass air flow through it. The system is controlled by the gas pedal, which is essentially a potentiometer in which the output voltage indicates a desired output angle in the throttle valve.

When the accelerator actuates, the opening angle increases, causing an increase in the effective open area of throttle valve, described by Eq. 1 [3], leading to an increase in the mass air flow, given in Eq. 2 [3]. Even if the downstream pressure increase causes a reduction in the mass flow, the passage area increase prevails.

$$Mth = \frac{Cd.Ath.Po}{\sqrt{R.To}}.\left(\frac{Pt}{Po}\right)^{\frac{1}{y}}.\left\{\frac{2y}{y-1}.\left[1-\left(\frac{Pt}{Po}\right)^{y-1/_7}\right]\right\}^{\frac{1}{2}} \qquad \text{Eq.1}$$

$$Mth = \frac{Cd.Ath.Po}{\sqrt{R.To}}.y^{\frac{1}{2}}.\left(\frac{2}{y+1}\right)^{\frac{(y+1)}{2.(y-1)}} \qquad \text{Eq.2}$$

where Po and To are respectively the upstream pressure and temperature, PT is the downstream pressure of the throttle valve, Cd is the discharge coefficient (determined experimentally), R is the Reynolds number, and y is the specific heat ratio.

The engine management system controls continually the air mass flow, and this data establishes the appropriate fuel injection period to obtain the desired stoichiometry (λ) given in Eq. 3 [4].

$$\lambda = \frac{\left[\frac{air.mass}{fuel.mass}\right] effective}{\left[\frac{air.mass}{fuel.mass}\right] ideal} \qquad \text{Eq.3}$$

As a consequence of an increase in the mass air and fuel flows, there is an increase in the engine rotation, determined by Eq.4.

$$air.mass.flow = n * \frac{pressure}{R * temperature} * volumetric.capacity * \frac{rpm}{120} \qquad \text{Eq.4}$$

3 METHODOLOGICAL ELEMENTS

The didactic kit development had the following major goals:

- Improve student knowledge on the internal combustion engines with electronic injection;
- Allow students to explore the microcontroller programing in vehicular applications;
- Improve student practical experience with vehicular sensors and actuators.

The access to signals of a real car system is challenging, which has worsened by the fact that the engine must be working, increasing concerns for the student safety. This didactic kit overcomes such difficulties, allowing students to familiarize with the intake air system and to develop projects involving mock-ups (prototype of a vehicle) and even real cars.

This methodological procedure allows students to work with a nearly real system and motivate them to develop sequentially several car systems. Therefore, this project aims to describe the intake air system, and later the students could develop other systems, such as the control of the throttle valve opening, MAP and MAF sensor reading, commonly used in electronic control unities (ECU's) of engines.

It is expected that students acquire knowledge on the hardware developed in the air intake system management for internal combustion engines, and be able to develop control software. Additionally, it is expected that students develop practical skills with sensors and actuators, and be able to correlate the experimental data of the kit with a real automotive system.

4 SYSTEM DESCRIPTION

4.1 General Description

Figure 3 presents the block diagram of the system and its experimental realization. The didactic kit consists of the throttle valve, the electronic gas pedal (drive by wire), the vacuum generator system (using a vacuum cleaner), the heating system (using a hairdryer), temperature and pressure sensors (MAP), an air mass flow sensor (MAF), and a power control system.

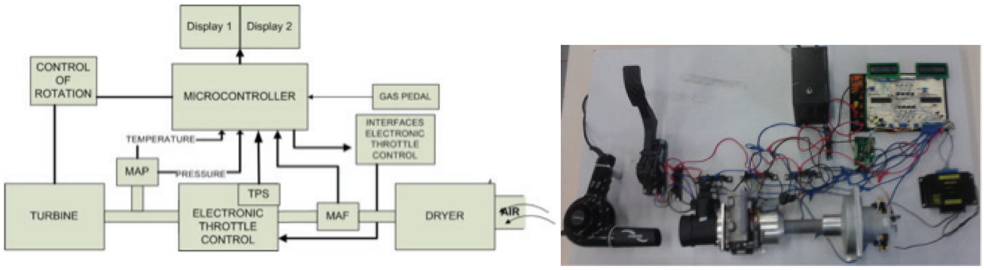

FIGURE 3. *Block diagram and didactic kit.*

4.2 General Description of the Control Circuits

The electronic control system of the intake air system consists of a pair of microcontrollers (PIC16F877A), one for the control of the intake air and the other for the turbine rotation. There are two LCD displays and two additional power circuits that control the throttle valve (Darlington driver, with the BD137 e 2N3055 transistors, and bridge H driver from Freescale CI MCP33926).

Figures 4 and 5 present the block diagram of the electronic system, along with the real electronic system developed here.

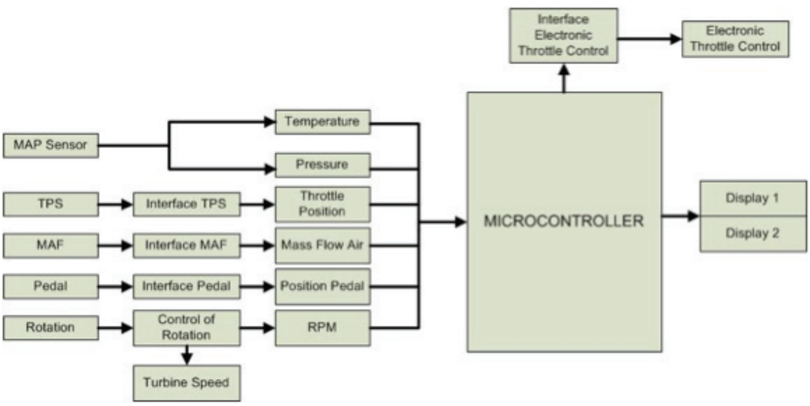

FIGURE 4. *Block diagram of the control circuit of the intake air system.*

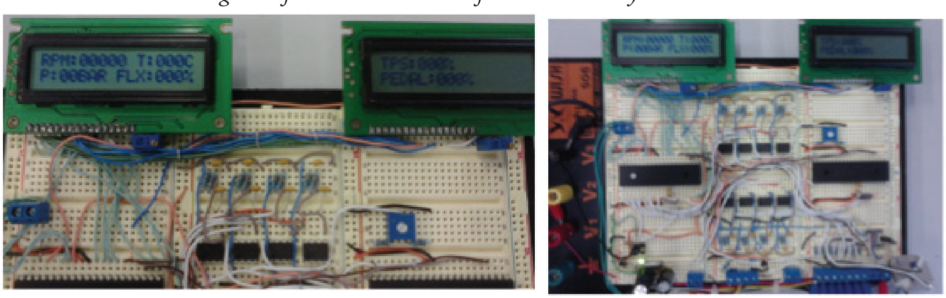

FIGURE 5. *Electronic control system.*

4.3. Project Developed by the Students

The system operates as follows. Starting from a voltage, generated by the electronic gas pedal, a microcontroller besides a power circuit control the opening of the throttle valve. Consequently, the air flow is controlled by engine. This flow is generated by a depression using a vacuum clear turbine of 1.3 kW. Another microcontroller controls the turbine rotation and the Triacs conduction angles. In parallel, temperature and pressure are measured by the MAP sensor, while the air mass flow is measured by the MAF sensor. Therefore, the student follows the project procedures shown in Figure 6.

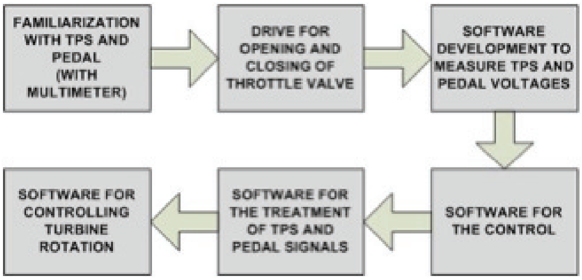

FIGURE 6. *Project procedures for students.*

In a first step, the student gets used to the characteristics of resistance and voltage in the positioning sensor of the valve as well as of the pedal, without using a microcontroller. In a second step, the student works on the control of the throttle valve, generating PWM signals with different duty cycles, 90% to open, 10% to close, and 50% to remain with no motion, closing and opening in synchronized with the throttle valve.

In a later moment, the student starts the measurements on the valve position using the TPS signal, with the results shown in the LCD display. Finally, the control code can be developed, in which the analogic signal of the gas pedal is converted to a digital form, generating a reference signal for the throttle valve position.

After that, the student focuses on the control codes for the pressure and air mass intake measurements, which are based on specific datasheets of each sensor, moreover these measurements are shown in a display LCD. Finally, the student works on the coding to control the turbine rotation based on the positioning of the throttle valve.

5 CODES DEVELOPED BY THE STUDENTS

The software used the C language and could be divided in three parts. The first part, described in Figure 7, controls the opening of the throttle valve as a function of the gas pedal position. A reference for the throttle valve position is generated from the analogic signal, which is compared to the current position. If the two values are within some acceptable interval, the values related to the gas pedal and throttle valve positions are updated and shown in the display, while a new measurement on the gas pedal position is executed. If this is larger, the duty cycle of the PWM signal is increased, being monitored until reaching a pre-determined acceptable interval. On the other hand, if this is smaller, the duty cycle of the PWM signal is reduced.

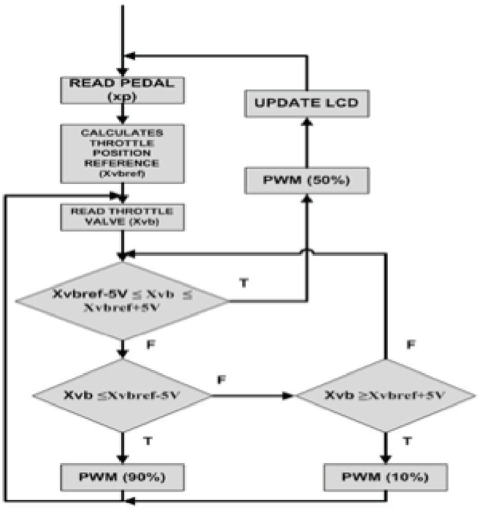

FIGURE 7. *Software flowchart of the first block.*

Figure 8 shows the flowchart of the second block. It consists essentially in the conversion of analogic signals (from the MAP and MAF sensors) in digital ones, and an indexer for the predetermined matrices, and presents the results in the second display.

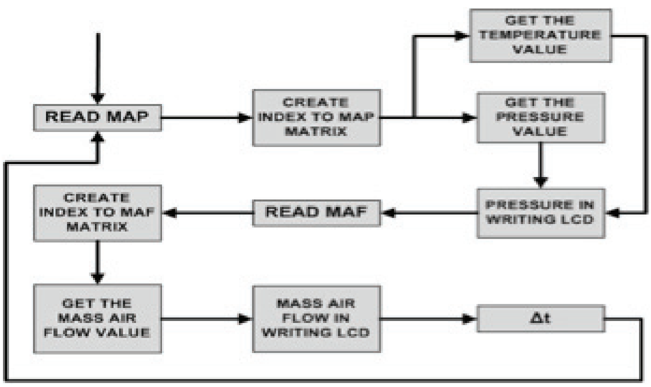

FIGURE 8. *Software flowchart of the second block.*

Figure 9 shows the flowchart of the third block. It controls the rotation by determining the conduction angle of the Triacs, starting from the throttle valve, using the SPI communication with the first microcontroller.

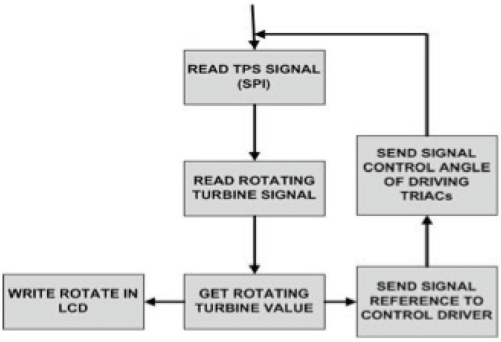

FIGURE 9. *Software flowchart of the third block.*

6 EXPERIMENTAL DATA

To execute the experiment, we established a voltage scale for the gas pedal position, with steps of 0.5V, with a maximum value of 4,98V. For each step, we measured the voltage in the TPS, in the MAP and MAF sensors, and the turbine rotation. Table 1 presents all the data obtained by this procedure.

TABLE 1. Data obtained by sensors in the test of the didactic kit.

Pedal		TPS		VXVBref	Turbine	MAP		MAF	
A/D	Voltage (v)	A/D	Voltage (v)	A/D	RPM	Voltage (v)	Pressure (Kpa)	Voltage (v)	Mass Air Flow (kg/h)
39	0,78	56	1,24	62,83	3780	2,99	73,94623656	1,55	37,306
60	1,28	78	1,6	77,53	3540	3,23	79,88172043	2,24	88,531
86	1,78	94	1,94	95,73	3240	3,44	85,07526882	2,46	108,792
110	2,28	112	2,28	112,53	3000	3,58	88,53763441	2,6	122,594
135	2,78	127	2,59	130,03	2800	3,66	90,51612903	2,53	115,239
159	3,28	143	2,92	146,83	2100	3,7	91,50537634	2,32	95,899
188	3,78	161	3,31	167,13	1200	3,72	92	1,86	55,809
196	4	168	3,45	172,73	600	3,73	92,24731183	1,41	29,355
222	4,53	184	3,78	190,93	0	3,73	92,24731183	0,05	0

The table presents the voltage corresponding to the pedal position, and the TPS, both in voltage level and A/D value, which is the format appropriate for the microcontroller. The table presents the VXVBref, which is the relation between the pedal position and the reference TPS value for the control of the throttle valve. The table also presents the voltage values of the MAP and MAF sensors, computed using the sensor datasheets.

7 CONCLUSION

In summary, we have shown that the didactic kit represents a powerful tool to study vehicular embedded electronics. Students that work with the kit can develop several educational elements, from theoretical aspects to practical ones, such as the electronic injection in the courses of internal combustion engines and all the related sensors. Additionally, the student can improve knowledge on microcontrollers and its software programming, develop electronic circuits and codes to interact with several parts of the electronic injection system, such as the throttle valve, MAP and MAF sensors.

In order to evaluate the didactical gains with the use of this system, we observed considerable gains in the complexity of the graduation projects of students. Additionally, we observed good improvement on the student understating, in the following semesters, of automotive related electronics.

In a near future, this project will be extended to other systems involved in the combustion engine. This will allow building a complete electronic kit for an engine management, developing mathematical models of the system and transfer functions. With such mathematical models, it would be possible to develop microcontroller systems capable of changing the setpoint, in addition to the protection of the system to external disturbances.

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205 A COMPARATIVE ANALYSIS OF THE PRE-ENGINEERING CURRICULA OF THREE INTERNATIONAL EDUCATIONAL SYSTEMS

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ABSTRACT

Industrialization at any level requires the availability of a labour force that is well-trained and capable of participating fully in the development of new products or re-engineering old products. In recent times, a number of countries, Ghana, Jamaica and the USA have expressed concern about the availability of a labour force that can maintain their competitiveness and innovation in engineering and science. The technical labour force required ranges from vocational technical graduates as mid-level engineers or technicians, and the production of graduates from tertiary educational institutions with bachelor's and post-graduate degrees. The questions that must be addressed in the area of labour force development include not only the numbers that are produced from year to year but also with regard to the quality of the labour force that is produced. With the aging of the current labour force, a country or a region must plan carefully for the replacement of its labour force in order to sustain growth in its economy for the benefit of its citizens. The quality of the product of any institution that participates in the production of graduates depends on the preparation received by students prior to enrolling in post-secondary institutions. In this paper, the pre-Engineering curricula of secondary or high schools in three geographical regions of the world, the USA, the English speaking region of West Africa, and the Caribbean are compared in terms of their curricula content to prepare students for entry into college and for them to succeed and become members of the Science, Technology, Engineering and Mathematics (STEM) workforce. A historical perspective is taken in the comparative analysis as it relates particularly to the influence of technology on the delivery, the learning and practice of engineering and science. The intent of this paper is to describe the commonalities of the three pre-Engineering curricula and to identify areas in which the three regions can improve in order to make their graduates better prepared and desirable for employment not just locally but anywhere in the world. The paper begins with a description of the pre-engineering curricula of the three regions in which commonalities and differences are noted and highlighted. The paper concludes with recommendations for the three regions to implement in making their curricula more diverse in which opportunities exist for students to obtain training that makes them productive citizens of the global village. A final recommendation is for the regions of English speaking West Africa and the English speaking Caribbean and the USA to form collaborative partnerships with other institutions in and outside of their regions in order to share in the best practices required to enhance the educational experiences of their students.

Keywords: STEM education, pre-engineering, curricula.

1 INTRODUCTION

From a historical perspective, changes in the engineering profession and engineering education in the so-called developed countries have kept pace with changes in technology and society. Typically, engineering disciplines were added and curricula in undergraduate and advanced engineering programs were created to meet the critical challenges in society and to prepare the workforce required to integrate new developments into the economy. The landscape is different today; the world is "flatter" [1], society is continually changing and the disciplines must also change to adapt to remain relevant. The engineering profession and engineering education, whether in the developed or underdeveloped world must anticipate needed advances and prepare for a future in which the needs of society are met efficiently in an environmentally friendly manner. It is for these reasons why discussions continue to be held and documented, for example, [2], on the future of the engineering profession and education. Reforming education, especially in the disciplines of Science, Technology, Engineering and Mathematics (STEM) has received wide publicity especially in the United States and a perfect direction is yet to emerge. In bringing his style of reform to his nation, the President of Ecuador recently declared [3] that his country probably has the worst universities in South America, and consequently a proposal will be implemented in which admission to the country's public universities will be based on an aptitude test along the lines of the Scholastic Aptitude Test (SAT) in the United States.

The gap between developed and some developing countries seems to be widening even though the world has become "smaller" with the availability of the internet, the use of broadband resources and other communication technologies. Whereas such resources are used in the developed countries to enhance the teaching and learning of engineering principles through the conduct of problem-based learning experiences across continents [4] at the university (college) level, the resources of the internet are not widely available uniformly in all regions of the world. With lack of infrastructure to adapt quickly to societal and technological changes especially in education, developing countries continue to depend on a workforce that is imported [5] as part of a package that in all cases involve loan agreements for the production of a resource such as oil that ultimately is exported to meet loan payments.

In light of the disparities in the delivery of education and training to students in developed and developing regions of the worlds, the intent of this paper is to describe the commonalities and differences in the three pre-Engineering curricula of three regions of the world and to identify areas in which the three regions can improve in order to make their graduates better prepared and desirable for employment not just locally but anywhere in the world. The regions selected are the USA, Ghana, an English speaking region of West Africa, and Jamaica in the Caribbean. The paper begins with a description of the pre-engineering curricula of the three regions in which commonalities and differences are noted and highlighted. The paper concludes with recommendations for the three regions to implement in making their curricula more diverse in which opportunities exist for students to obtain training that makes them productive citizens of the global village. A final recommendation is for the regions of English speaking West Africa and the English speaking Caribbean and the USA to form collaborative partnerships with other institutions in and outside of their regions in order to share in the best practices that may be implemented to enhance the educational experiences of their students.

2 REQUIREMENTS FOR AN ENGINEERING DEGREE

As a professional degree, most countries have a process in place to ensure that quality is maintained in the curriculum of an engineering degree program. In the United States, for example, the body responsible for ensuring quality in engineering programs is the Accreditation Body for Engineering and Technology, ABET [6]. Its members include professional organizations such as the American Society of Mechanical Engineers with members that determine accreditation criteria. An engineering program could lose its accreditation if the program is determined, through a long process of review which includes site visits, that the program is deficient in providing quality education to students. Prior to a site visit by representatives of ABET, the engineering program faculty and institution must submit a self-study report that documents the results of a critical evaluation of the program. A key aspect of the self-study is an assessment of the program by its constituents and the use of the assessment report in making improvements in the program.

A number of criteria have been set by ABET that must be met by engineering programs to obtain accreditation. The curriculum requirements specify subject areas appropriate to engineering but do not prescribe specific courses. The curriculum components include at the minimum the following [6]:

- one year of a combination of college level mathematics and basic sciences (some with experimental experience) appropriate to the discipline. Basic sciences are defined as biological, chemical, and physical sciences. One year is the lesser of 32 semester hours (or equivalent) or one-fourth of the total credits required for graduation.
- one and one-half years of engineering topics, consisting of engineering sciences and engineering design appropriate to the student's field of study. The engineering sciences have their roots in mathematics and basic sciences but carry knowledge further toward creative application. These studies provide a bridge between mathematics and basic sciences on the one hand and engineering practice on the other. Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs.
- a general education component that complements the technical content of the curriculum and is consistent with the program and institution objectives.

Additionally students must be prepared for engineering practice through a curriculum that includes a major design experience in the final year of study based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints.

Tertiary educational institutions in Ghana are accredited by the National Accreditation Board (NAB). As a unit under the Ministry of Education, the responsibility of the Board is to review and recognize an educational institution for meeting satisfactory standards in performance, integrity and quality. The function of this body is similar to that of a regional accrediting body such as the Middle States Association of Colleges and Schools Commission on Higher Education (MSCHE) in the US. Like the MSCHE, the process of accreditation as implemented by NAB begins with the completion of a questionnaire, the submission of a self-evaluated report, or a business plan, by the educational institution and a visit by a team of evaluators. On completion of its work, the evaluating team communicates their decision which can be appealed to the Minister of Education if not favorable. Unlike ABET, there is no specific body in Ghana that independently accredits programs in the engineering disciplines. Similar to the accreditation process in Ghana, higher educational institutions in Jamaica are accredited by the University Council of Jamaica (UCJ), a board that was created by an act of parliament in 1987 [7]. The Council is a statutory body under the Ministry of Education. Under the Council are a number of Boards of Studies in a number of disciplines including engineering that, among other responsibilities, establish minimum acceptable standards for programs of study leading to the award of degrees and other certificates. As an example of the distribution of number of credit hours required for the receipt of a

TABLE 1. Credit Hour Allocation in Core and Elective Subjects.

	Howard University, USA		KNUST, Ghana	
Core/Electives	# of Credit Hours	% of Total	# of Credit Hours	% of Total
Social Science/Humanities	23 (includes 2 hours of PE)	18.0	12	8.5
Math/Eng Science	68	53.0	85	60.7
Experimentation	9	7.0	4	2.9
Design	22	17.2	23	16.4
Electives	6 (Free Electives)	4.7	16	11.4
Total Credit Hours	128		140	

Bachelor's degree in Mechanical Engineering, Table 1 shows a comparison between the curricula of two universities in the USA and Ghana. Except for some disparities, the curricula of both departments appear to have identical weighted allocations of credit hours to the various core/elective areas. The curriculum at the Kwame Nkrumah University of Science and Technology (KNUST) has more than seven per cent of credit hours allocated to mathematics and engineering science whereas more weighting is allocated to Experimentation courses at Howard University than at the KNUST. The allocation of credit hours to the design stem of each curriculum is practically identical. Although Howard University allows students to take four electives (two in the discipline, and two from other disciplines) for a total of 12 credit hours, the program at the KNUST allows students 16 credit hours of elective courses that are for the most part discipline focused and are taught as mechanical engineering courses.

3 EDUCATIONAL SYSTEMS

The educational systems in the three subject regions of the paper have varied elements of requirements from primary education to the award of a bachelor's degree. The paths leading to the bachelor's degree for Jamaica, Fig. 1, and the Caribbean have elements that are remnants of the British educational system with some modifications. Starting at the end of basic primary education, students are expected to take a common entrance examination to qualify for entry into a secondary high school. The high school experience culminates in either the student opting to take the General Certificate of Education (GCE) at the Ordinary Level or an equivalent exam, the Caribbean Secondary Education Certificate (CSEC) given by the Caribbean Examinations Council (CXC). Depending on the performance on the CSEC examination, a student may proceed with continuation of secondary education at an advanced level or enrol in a community college or apply to pursue a Higher National Diploma (HND) certificate at a polytechnic institution such as the University of Technology, Kingston. The latter group of students may on the completion of polytechnic or community school education continue to pursue higher education at the University of West Indies to obtain a bachelor's degree. A student who continues advanced secondary education takes the Caribbean Advanced Proficiency Examinations (CAPE) and proceeds to the University of West Indies to pursue a bachelor's degree program. The CAPE is equivalent to the British Advanced Level examination [8].

Except for differences in examination requirements, the educational systems of the USA and Ghana are identical in the path that is followed to obtain a bachelor's degree. Beginning with primary and middle school education, both systems require students to pass standardized examinations before proceeding to high school (HS) or senior secondary school (SSS) in the case of Ghana. Disregarding the number of years spent in high school, a student must pass yet another standardized examination before proceeding to the university. In Ghana the examination is referred to as the WASSCE, the West African Senior Secondary Certificate Examination. In the US the requirements vary from state to state but one requirement that is standardized is the SAT or its equivalent the ACT. Each university, public or private, sets its own entry requirements for entry to pursue a bachelor's degree.

3.1 Pre-Engineering Curricula

Students are exposed to a lot more subjects in secondary education in Jamaica. But secondary education is the stepping stone and the foundation to students' future career and further education. Foreign subjects include Spanish, French and German. Other

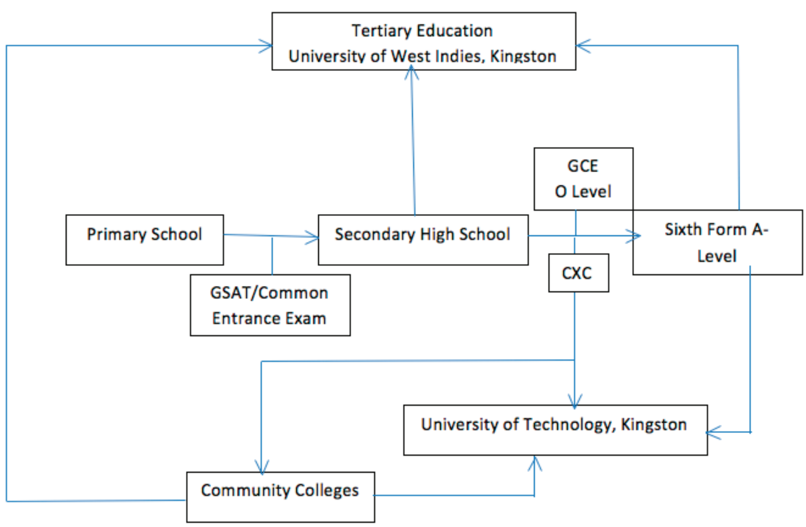

FIGURE 1. *Flowchart of educational system in Jamaica (those of Ghana and USA are embedded implicitly).*

subjects are English Language, English Literature, Mathematics, Integrated Science, Food and Nutrition, Religious Education, Clothing & Textiles and Art & Craft. By the

time students reach the fourth form of the five year secondary education, they already have an idea as to what they want to be in life and as such are grouped according to their career choice and the subjects which will enable them to achieve their goals. They are given the option to choose their subjects with the understanding that Mathematics and English Language are compulsory. At this level of education in Jamaica, students are now introduced to Chemistry, Physics, Human & Social Biology and Biology.

The senior secondary school curriculum in Ghana operates in a three year academic cycle; from form one to form three. The beginning of the first academic year marks the enrolment of the student in the assigned institution, while the ending of the third academic year marks the graduation of the student. During their three year enrolment students are provided with text books for their studies, prescribed by the Ghana Education Service. The curriculum follows a prescribed calendar in which students are taught from January to December over a period of three terms, comprising a total of forty weeks per year. The academic assessment of students is undertaken twice within a term, with students writing a mid-term examination and an end-of-term examination, which both contribute to the students cumulative assessment score. In the public schools, all students take a Core curriculum consisting of English Language, Integrated Science, Mathematics, and Social Studies. Each student also takes three or four Elective subjects, chosen from one of seven groups: Sciences, "Arts" (social sciences and humanities), Vocational (visual arts or home economics), Technical, Business, or Agriculture. As stated earlier at the end of Senior Secondary School (twelfth grade), all students take WASSCE, in each of their seven or eight subjects. These exams are given nationwide in May-June each year, but the results are not available until the following October. Grading is exceptionally tough: fewer than 3% of grades are A's, and 40% of students fail any given exam. C's and D's can be quite competitive grades.

There is wide variance in the curriculum required each year but many American high schools require that courses in the "core" areas of English, science, social studies, and mathematics be taken by the students every year although other schools merely set the required number of credits and allow the student a great deal of choice as to when the courses will be taken after 10th grade. The majority of high schools require four English credits to graduate. Typically, all four levels of English classes include both standard and honors options. Advanced English may feature Advanced Placement (AP) opportunities to earn college credits, as well. Generally, three science courses are required. Biology, chemistry, and physics are usually offered. Courses such as physical and life science serve as introductory alternatives to those classes. Other science studies include geology, anatomy, astronomy, health science, environmental science, and forensic science. High school mathematics courses typically include remedial pre-algebra, algebra I, geometry, algebra II, and trigonometry. Advanced study options can include pre-calculus, calculus, statistics, and discrete math generally with an opportunity to earn Advanced Placement (AP) or International Baccalaureate (IB) accreditation. Usually, only three math credits are required for graduation (although four is recommended). Some high schools have now raised the requisite number of credits to four. Not all high schools contain the same rigorous coursework as others. Most high and middle schools have classes known as "honors" classes for motivated and gifted students, where the quality of education is usually higher and much more is expected from the enrolled student. Some states and cities offer special high schools with examinations to admit only the highest performing students, such as Northern Virginia's Thomas Jefferson or the Maryland's Montgomery Blair High School. States that have well-developed community college systems, often provide mechanisms by which gifted students may seek permission from their school district to attend community college courses full-time during the summer, and during weekends and evenings during the school year. The credits earned this way can often be transferred to one's university, and thereby facilitating early graduation.

3.2 Comparative Analysis of Curricula

There are a number of variances in the high school or secondary school curricula of the three regions that are profiled in this paper. In the USA and Ghana, pre-tertiary education ends at the equivalent of the twelfth grade whereas in Jamaica, one has to spend another two years in advanced courses in the secondary school sixth form level before entry into the university. Historically, Ghana has in the past implemented a scheme similar to that currently in place in Jamaica, the two being former British colonies, but chose to design a system in line with the system of the USA. In doing so, however, secondary school education appears to be suffering from the politics of education in which the duration of high school has been changed from there to four years and soon to be changed to three years. As it relates to Engineering, it is interesting to note that the curricula of Jamaica and Ghana include a core course, Integrated Science. The students in Jamaica are however given the chance to select options in the fifth year to pursue rigorous science classes such as Physics, Chemistry and Biology. Such options are not available in the Ghanaian system and unlike the US educational system, such courses are not required in the university engineering curriculum [4].

4 SUMMARY AND RECOMMENDATIONS

A review of the pre-engineering curricula of three regions of the world, the USA, Ghana and Jamaica has been described in this paper. Beginning with requirements for the degree of engineering the paper examines the level of preparation that is offered to students in the three regions. Both Ghana and Jamaica have made changes to the system inherited from the British; whereas Ghana has made radical changes to the educational system for better or worse, Jamaica seems to be taking the rigor out of the system by instituting its own examination requirements that are considered to be easily passed by students. To better prepare students to succeed in Engineering, the US appears to be investing a lot of resources based on the number of grant funding opportunities to design and implement enrichment programs for students during the academic year and particularly during the summer periods. Such opportunities may not be available to students in Jamaica and Ghana; in the absence of such programs during the long vacation or summer period, the longer duration of secondary education in Jamaica should be used effectively in preparing students to succeed in engineering. In all three cases however continuous assessment of the curricula by representatives of all stakeholders must be instituted and implemented in order to better prepare a labor force that is capable of responding quickly to the technological changes in the society.

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207 MATHEMATICAL LITERACY FOR ENGINEERING MAJORS

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ABSTRACT

In this paper, we provide a status report on the activities of an interdisciplinary task force at The Ohio State University (OSU). The task force was assembled to define a set of competencies that might used in developing a first year mathematics course aimed at fostering mathematics literacy amongst engineering students. We utilized the KOM project framework of mathematical competencies to analyse reports from the task force members and compare with interviews of engineering faculty members. We found four common themes: (1) A desire to work within the existing academic structure, (2) a preference for engineering students to see and apply mathematics as a tool, (3) the view that mathematical thought is separate and distinct from engineering thought, and (4) the want for students to be able to solve problems with too little or too much information given. Curricular implications and possible additions to the KOM framework specific to engineering students will be discussed.

Keywords: Mathematical literacy, KOM project, curricular change.

1 INTRODUCTION

In the United States of America (USA), there have been numerous calls to increase the number and quality of Science, Technology, Engineering, and Mathematics (STEM) majors, especially engineers to meet the ever growing societal and cultural needs [1], [2]. It is imperative to open a discussion about ways to improve engineering education, however the emphasis should perhaps be placed on improving the quality engineers over the quantity. One possible, and arguably important, way to begin is to examine what mathematics the engineering students need and how they may need to be able to use it. A recent presidential report in the USA has called for another reform movement to initiate empirically based teaching methods in mathematics undergraduate classrooms [3]. Despite the merit of such efforts, it seems reasonable to first explore, in depth, the type of mathematical competencies reformed instruction may need to nurture in students. Our work will provide a status report of an interdisciplinary task force assembled at the OSU to take first steps in the direction of defining mathematical competencies that might be used to create a first year course aimed at fostering mathematical literacy among engineering students. While the construct of mathematical literacy has been a part of discourse of mathematics reform for decades, neither its principles not its implications for engineering education has been addressed in the past. We compare reports from task force members to interviews with engineering faculty members to identify possible competencies that both groups find vital for engineering students. We then discuss potential clashes in theoretical ideas between departments that might stall this and further curriculum changes in engineering education.

2 THE OHIO STATE UNIVERSITY CONTEXT

The Ohio State University has an annual enrolment of around 55,000 students, making it the second-largest educational institution in the USA [4]. The College of Engineering alone houses about 6,000 undergraduate students each year. All engineering students are required to enrol in basic physics and mathematics courses and serve as the largest audience for the mathematics and physics course offered at OSU. In order to accommodate the large number of students, course enrolments are split into multiple large lectures and supplemented with smaller recitation sections. This arrangement is typical of large educational institutions in the USA. At OSU, consistent with common practices throughout the USA, mathematics is typically sequenced at the undergraduate level as differential calculus (limits & continuity, derivatives, optimization, etc.), integral calculus (integrals, FTC, trig. & inverses, etc.), sequences and series (indeterminate forms, Taylor's formula, improper integrals), multivariate calculus (partial differentiation, Lagrange multipliers, etc.), and then differential equations. Note that with the large number of students, if this first year course were created, it would provide a unique opportunity to document reform in mathematics, physics, and engineering education.

3 UNDERGRADUATE STEM REFORM IN THE USA

Many researchers and professional organizations have expressed a lack of satisfaction with the substance of undergraduate student knowledge, especially in STEM programs [2]. Past reform efforts in undergraduate mathematics education were aimed at calculus in the 1990's, which had mixed results [5]. A similar push for reforming physics courses also occurred at around the same time. The goals of both waves of reform remain unfulfilled. Collectively, there is evidence that efforts to reform university mathematics and physics courses level have failed to provoke lasting learning outcomes for students [6].

Reform in engineering education also began around the 1980's in the USA, but reaching its goals still remains elusive as well [7]. In particular, engineering educators endeavour to increase the flexibility of engineering students' thinking as well as their ability to integrate knowledge from mathematics, science, and engineering. Currently at Wright State University, there is an engineering mathematics that teaches mathematics from the perspective of engineering problems. Products and results from the Wright State study include a book, assignments, and retention rates [8]. Although this is encouraging, it still leaves little concept of how one might apply this at other universities.

Note that many, if not all of these reform efforts have attempted to implement change while working within the pre-existing academic structure so as not to disturb programs. Reports do not indicate whether such efforts were guided by deep discussions regarding the content and skills needed by engineers. Additionally, although engineering educators suggest an individualized approach, rather than a "cookie cutter" uniform approach to developing engineering program reform, it can lead to different teams speaking of the same idea, but calling it different names. We propose speaking of reform, both in mathematics for engineering students, and perhaps all of engineering, using competencies. Reasons for this will be more fully developed in our conceptual framework.

4 CONCEPTUAL CONSIDERATIONS

As mentioned above, many of the reform efforts use the same ideas but called them by different names. In this section, we define the main conceptions and underlying assumptions we use throughout this work.

There have been many definitions, re-definitions, and re-namings of mathematical literacy in the literature over the years. Instead of taking the readers through this history, one may see a full report in Steen's Mathematics and Democracy [9]. As it pertains to the ongoing effort at OSU, we view mathematical literacy to mean: "an individual's capacity to identify and understand the role that mathematics plays in the world, to make well-founded judgments and to use and engage with mathematics in ways that meet the needs of that individual's life as a constructive, concerned and reflective citizen" [10]. We build on this perspective by asserting that the specific nature and parameters of what mathematical literacy depends largely on the audience for which it is described. For example, mathematical literacy, as it is needed in the engineering field, is much different from the type of mathematical literacy needed by professionals in other areas such as fiction writer or teacher. This supports the view that the nature of mathematics needed in different professions is highly specialized and catered to the demands of particular careers [11].

With this perspective in mind, then, the goal of engineering programs should be to produce graduates who are not only well versed in the mathematical symbolism, as taught in formal courses, but are also capable of using those tools fluently and appropriately in contexts. As such, newly defined competencies must include the ability to go beyond composing and reading mathematical statements. Skills needed go beyond the ability to translate physical situations to mathematical representations since a translator would only search for terms in an attempt to reproduce the original situation in words and general this is done from the second language to the first. We posit that two subtleties are overlooked by the translation metaphor: (1) Translation implies that one moves between two different languages when, throughout history, mathematical formalism has been used to articulate natural phenomena in both science and in every day life. (2) Literacy in mathematics entails both the dexterity and the resourcefulness to recognize and employ mathematical principles and structures. Thus we suggest that the full concept of mathematical literacy is closer to multilingualism, or the ability to express one's ideas and perceptions in multiple languages. In this case, it is an ability to express one's ideas and perceptions using physical principles and multiple representations while being aware of how the two connect. Schwarzkopf's work suggests STEM students must be able to simultaneously restrict the real world to mathematically relevant aspects while structurally enriching the real world with mathematical structures [12].

4.1 Conceptual Framework

Niss & Højgaard identified eight competencies that are split into two categories and can be seen in Figure 1 [13]. The categories, asking and answering questions with and about mathematics and dealing with mathematical language and tools, are general and the authors warn of over-interpretation. The authors acknowledge that there will be overlap between the categories of competencies and even individual competencies. Thus in the description of the competencies, we also include a few of the connections and overlaps.

Asking and answering questions in, with, and about mathematics includes the competencies mathematical thinking, problem tackling, modeling, and reasoning. People competent in mathematical thinking should be able to recognize mathematical objects, generalize their properties, and understand the implications that arise during both of the previous stages. In addition, this competency requires users to be familiar with and able to pose the types of questions regularly asked in mathematics as well as hypothesize about probable answers to those questions. The problem tackling competency is being able to recognize problems, interpret them, and then solve in multiple ways. Note that we do not consider procedural skills exercises as "problems", but are referring to non-routine situations. The modelling competency is characterized by being able to evaluate the appropriateness of current models, as well as take a new situation, mathematize it, evaluate the mathematics version of the situation, and either move forward to solve, or revise the model if necessary. Those competent in reasoning must not only be able to use formal mathematical proofs, but be able to justify mathematical reasoning and answers to themselves and others.

In the second category, dealing with mathematical language and tools, the competencies are: aids and tools, communicating, symbol and formalism, and representing. First, the aids and tools competency requires people to have knowledge of the multitude of aids and tools necessary to utilize mathematics and then being able to evaluate those tools to make decision about what particular tool to use at a particular moment. The communicating competency includes an awareness of different levels of formalism in mathematics as well as using them appropriately to express mathematical ideas to a variety of audiences. To be competent in symbol and formalism is in a way is related to the modeling competency because it requires students to be able to constantly modulate between symbolic mathematical representations and "natural language" [13]. Lastly the representing competency includes familiarity with multiple representations, recognizing relations between them, and the ability to choose the most effective representation in a given situation.

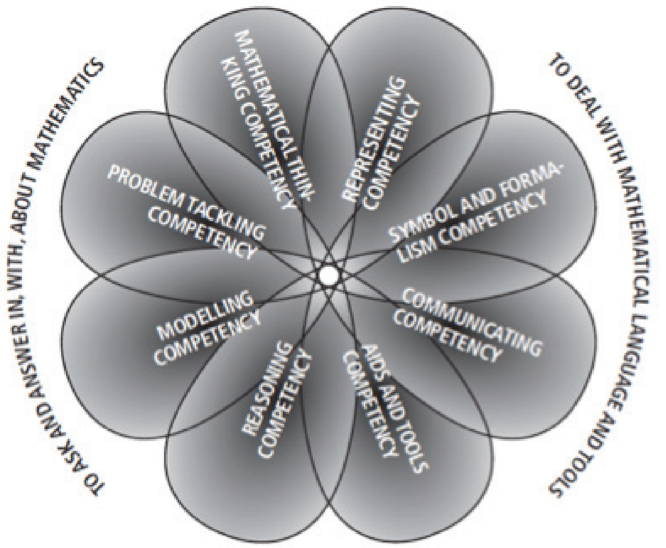

FIGURE 1. *Visual of KOM project's competencies [14].*

5 METHODOLOGY

Two sources of data were considered: (1) reports from task force members and (2) interviews with engineering faculty members. One task force member provided verbal reports on activities conducted at meetings. In addition, five engineering faculty members from various departments were interviewed. The interviews were part of a larger study of professors from mathematics, science, and engineering backgrounds to determine mathematics competencies needed for first year engineering students.

Each professor was interviewed once for approximately one hour. The interviews were transcribed once and then listened to again while editing the transcription. Each transcript was indexed [14] and then analyzed in light of the other interviews. In addition each transcript was coded according to the KOM competencies. Sample interview questions for the professors include:

1. Questions about remediation:

a) How do you assess when your students need remediation?
b) What do you assess when you feel remediation is needed?
c) How do you meet those needs?

2. What does it mean to do mathematics as an engineer? This question is adjusted for the discipline of the interviewee.

Eight task force reports, lasting between thirty and sixty minutes, were also compiled. Field notes were taken during this time. The task force member shared updates on activities conducted during the meetings, including challenges faced and consensus reached. A sample question discussed in the task force reports is "What challenges or agreements emerged in the last meeting?" This question allowed us to vet the professor interviews against the task force reports to identify possible points of contention and accord between the different departments involved.

6 RESULTS

Four specific thematic features were prominent in both data sources:

Engineering professors wished to work within the pre-existing academic framework. One professor, when asked about how to encourage students to problem solve responded by saying the engineering professors, "change the way in which we present the information so that they have to do a little bit of research." When asked what might happen when students need to program Taylor series before encountering the concept in a mathematics course, the same professor offered that the students needed to be capable of programming it but need not appreciate its mathematical significance. In such an approach, the conceptual connections are de-emphasized and activities within the existing classes are emphasized.

Engineering professors preferred their students learn to see mathematics as a tool. One interviewee described mathematics professors as handing the engineers a wrench, hammer, screwdriver, etc, so that they could use them to solve practical problems. Other task force members have reported that they do not believe students need to understand abstractness in mathematics in any form so long as the students can use the equations to solve problems in their engineering classes. In the language of the KOM framework, the engineering professors said they wished their students satisfied the modeling competency. If students were proficient in the modeling competency, they could "implement a mathematisation of this situation, i.e. translating the objects, relations, problem formulation, etc. into mathematical terms resulting in a mathematical model" [13].

Engineering professors referenced mathematical thought as separate and distinct from engineering thought. One professor described the "boxes" that students have in their heads: "math box," "English box," "science box." Another went further and stated, "We really want the students thinking in an engineering way 95% of the time. And then maybe a little bit leftover for math thinking or physics thinking." The separation that the engineering professors spoke of seems to stem from a belief that mathematics is purely an abstract subject with no application. The professor that spoke of the engineering way of thinking 95% of the time later expanded his reasoning and described how mathematician sit in their offices and only prove theorems without knowing the practical applications at all. Thus it seems that the engineering professors in our study and on the task force do not see the modeling competency as part of mathematics. That is, they do not see the ability to "work with the resulting model…as well as validating the completed model by assessing it both internally (in relation to the model's mathematical properties) and externally (in relation to the area or situation being modelled)" as part of mathematics at all [13].

Engineering professors wanted to see their students exposed to problems with too little or too much information given. All of the engineering professors in interviews and in the task force reports mentioned that their students needed to be ready to deal with problems posed with too much or too little information given. That is, their students need to be able to make assumptions or look up information when too little information is given and on the other hand when too much information is given, be able to make decisions about what is important.

7 CONCLUSION

We continue to work towards the overall all goal of creating a STEM framework for mathematical literacy. From the task force reports and the professor interviews, though, it appears that professors from different technical backgrounds maintain contrasting views on the nature of mathematical thinking. These views naturally influence how they characterize mathematical literacy, as it pertains to their own areas. A re-conceptualization of a first year mathematics course for engineering students demands that these differences might need to be resolved first in order for reform efforts to be successful.

We posit that in the absence of a framework describing mathematical literacy that connects mathematical ideas and physics principles, the current educational outcomes expected of those entering the STEM community may remain unfulfilled. In recent years, there has been an increased emphasis on how mathematics may need to be taught to produce productive STEM graduates, especially engineers; however, a more fundamental issue is what mathematical competencies should form the basis of instruction. For example, from current data, the modeling competency seems to be extremely important for engineering students. Altering the core perspective of STEM education is not accomplished through instructional modifications, but entails building instruction, curriculum, and connectivity around mathematical literacy for STEM students. Such a perspective change must precede the development of curricula otherwise students will be left memorizing algorithmic approaches in the same ways that they have for years. Best said, we are trying to create "conditions which would avoid the so politically attractive "quick fix solution", where one merely attempts [reform] through cheap and easily effected cosmetic changes" [13].

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214 ROUGHLY RIGHT AND FAST: BACK-OF-THE- ENVELOPE CALCULATIONS FOR ESTIMATION, PROBLEM BOUNDING, AND DESIGN DECISIONS

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ABSTRACT

Capstone design project courses provide a rich environment for honing student critical thinking skills. Design projects at the concept development stage require many decisions to be made with a very compressed schedule, often without extensive data fidelity. The ability to make realistic estimations or so-called "back-of-the-envelope" calculations is an important skill for a practicing engineer, especially in our global economy, where time to market pressures limit time for repeated analyses. Without practice, unfortunately, engineering graduates may not have the confidence to effectively utilize these methodologies. This paper provides a brief literature review of efforts to develop the associated critical thinking skills and confidence to apply effective back-of-the-envelope estimation through capstone design courses. The paper then discusses specific exercises, associated teaching strategies, and vignettes from capstone design instructors and practitioners that can be used to foster critical thinking skills in undergraduate students.

Keywords: back-of-the-envelope, capstone design, critical thinking skills, estimation, order of magnitude

1 INTRODUCTION

Enrico Fermi, a member of the Manhattan Project, famously estimated the magnitude of a nuclear explosion by observing how far little scraps of paper displaced when dropped while the blast wave passed [1]. His estimate of 10 kilotons of TNT was within an order of magnitude of the 20 kiloton result arrived at by weeks' worth of detailed data analysis. Dr. Fermi was famous for challenging his students with these so-called "Fermi Problems." Capstone design students can benefit from similar estimations and order-of-magnitude calculations, especially in the early stages of their design projects during problem framing and conceptual design.

Capstone design projects require student designers to make hundreds of decisions to complete their work. Design decisions made early in the process, when information is the most scarce, have an enormous influence over the life cycle costs of the final product. In some cases as much as 80% of these costs are committed by the end of the conceptual design phase [2]. Due to academic (or market) time constraints, there is never sufficient time to do detailed analyses in these early stages. As a result, it is critical that design engineers be able to make competent design estimations but herein lies the rub: our capstone design students do not know how to make design estimations. We complain about this with our colleagues at our own institutions and they agree. Based on discussions with capstone design colleagues from other institutions we conclude the lack of design estimation skills is not a local phenomenon.

The open-ended nature of capstone projects means that there is no pre-determined solution to the various analyses and therefore no solution in the back of the textbook for comparison. As John Harte observes in his entertaining book, Consider a Spherical Cow, "the ordinary combination of university math and science courses does not prepare students well for solving a frequently occurring type of 'word problem'… The problems we confront outside the classroom rarely take the streamlined form most textbooks rely upon to test how well we've read each chapter." [3, p. xi] Students are therefore not well prepared to confront a challenging new messy problem. Further, how can the students trust the results of their analyses? Given the number of decisions required to arrive at a feasible design, is there time to complete a detailed analysis for each alternative?

> *"It seems to me that the engineering curriculum spends an outrageous amount of time on analysis and simple calculations, yet we at the capstone level often find ourselves coaching students on concepts that [we] would think they should have learned much earlier. My belief is that capstone instructors need to start making it clear that the curriculum needs to change so that students are better prepared at the capstone level to deal with the so-called 'back of the envelope' calculation and simple estimation."*

[Quotations in italics throughout this paper represent comments from capstone design instructors; the full list of contributors is included in the Acknowledgements section.]

Back-of-the-envelope calculations are used to provide informed, but rough, estimates that can provide a benchmark for comparison to detailed computational solutions. These rough estimates are extremely useful when time or finances do not permit pursuit of a rigorous Computer Aided Engineering (CAE) approach or other simulation. Ideally, prior coursework should provide the confidence to trust hand calculations so that CAE results can be verified prior to investing in expensive physical prototype testing. Personal experience and that of other colleagues suggests that students trust their CAE results more than the results obtained through estimation.

> *"I was talking with a capstone team and their hand calculation was 10 times above their FEA computer analysis results. Even though their computer analysis was providing the exact opposite numbers that one would expect when changing parameters they still trusted the computer FEA over hand calculations."*

It would seem that the estimation skills needed for capstone design courses are either not taught or taught but not learned in earlier engineering courses. "Rough estimation activities are found to be incongruent with typical undergraduate engineering curricula. ... Students do not learn important skills from the engineering science learning activities necessary for making rough estimates. Furthermore, students are developing engineering knowledge in ways that do not support estimation activity." [4, pp. 76-82]

"I emphasize the order of magnitude estimation approach with my students to make design decisions. Mainly, the reason I adopt this approach is due to my limited skill: I am thrilled if I can answer anything within an order of magnitude."

Our colleagues agree that design estimation skills are important and agree that our capstone students have poor estimation skills. While we have a few exercises we use to help improve our students' skills in design estimation, we were also curious about what our colleagues in the capstone design community were doing in their respective programs to improve estimation skills. Moreover, we recognize that design courses are a natural place to emphasize and value estimation techniques. "Where rough estimation and engineering science activities differ, design activities are similar… Design activities imbue a curriculum with qualities important to estimation activity." [4, pp. 82-83] As such, our goal with this paper was to weave techniques from our colleagues and the literature more broadly into our own courses and to share them with the capstone design community at large.

2 LITERATURE REVIEW

We expected to find a rich source of information on the topic of estimation in the engineering education literature. Unfortunately, we did not. We explored the following sources: the Journal of Engineering Education (JEE), the International Journal of Engineering Education, the conference proceedings of the American Society of Engineering Education (ASEE), Frontiers in Education (FIE), the National Collegiate Inventors and Innovators Alliance (NCIIA), as well as resources such as Engineering Village (EV) and Conceive-Design-Implement-Operate (CDIO). The most complete engineering-related source on estimation we found was Ben Linder's doctoral thesis, Understanding Estimation and its Relation to Engineering Education [4]. By far the largest source for estimation and problem bounding was in the Physics literature from sources such as the American Journal of Physics, and Quantum. Table 1 provides a snapshot of the sources, search terms, and resulting literature we identified.

TABLE 1. Source searched and results.

Source	Search terms	Number of results and relevancy
FIE	"estimation"	54 results, none relevant
FIE	"approximation and design"	44 results, none relevant
FIE	"design decisions", "problem bounding", "bounds", "design decisions", "order of magnitude"	no relevant results
FIE	"envelope"	9 results, 1 relevant [7]
NCIIA	"back-of-the-envelope" , "estimation" , "approximation"	1 result, 1 relevant [8]
EV	"back-of-the-envelope" and "design"	45 results, 6 relevant [9] - [14]
IJEE	"back-of-the-envelope"	6 results, 2 relevant [15] - [16]
JEE	"design estimation"	40 results, 3 relevant [17] - [19]
JEE	"back-of-the-envelope"	3 results, none relevant

For CDIO, "design estimation" maps into the CDIO Syllabus under the section 2.1.3 Estimation and Qualitative Analysis [18]. The CDIO Syllabus has been adopted by numerous universities around the world as a framework for improving the quality of engineering graduates.

3 ACTIVITIES CAPSTONE INSTRUCTORS USE

The following sections summarize activities and strategies that were submitted by capstone design instructors and/or found in the literature.

3.1 Short Activities

Table 1 lists short activities that can be introduced in the classroom with very little instructor preparation. The class can be divided up into small teams and given a short amount of time to come up with their estimates. Most can be solved in 5 minutes or less. The instructor may choose to work out a sample estimation problem to help break the ice. The student teams should all operate under the assumption that any team can be picked to present their solution and any team member may be selected to be the presenter. This simple constraint helps facilitate engagement amongst all participants.

Table 2: Short activities to develop estimation skills

- Estimate the power to drive a single nail into a 2'x4' board
- Estimate the number of dentists in LA
- Estimate the total distance that a soccer player runs/walks in a 90-minute game
- Estimate the weight of the Rocky Mountains
- Estimate the number of beans in the jar (show a jar full of beans)
- Estimate how far a Honda CR-V can drive on 1 mL of gas
- Estimate the cost of shipping an empty wine bottle from China
- Estimate number of ping pong balls that would fit in the classroom [19, p. 13]
- Estimate the thrust of a Boeing 747 engine [4, p. 29]
- Estimate the drag force on a bicycle and rider travelling at 20 mph (9 m/s) [4, p. 29]
- Estimate the energy stored in a new 9-volt "transistor" battery [4, p. 31]
- Estimate how much electricity could be produced by burning everyone's junk mail in the U.S., assuming a conversion efficiency from heat to electricity of 30% [3, p. 67]
- Estimate how high a person can climb on a liter of milk [3, p. 74]
- Estimate the weight of your arm (or leg) [13, p. 274]
- Estimate the weight of the library books in your institution's library [13, p. 276]

3.2 Strategies

Table 3 summarizes strategies used by capstone design instructors to teach general estimation-based design problem solving techniques. The instructor need not be an expert in the domain of the estimation problem space. Instead, the instructor needs to be the strategy guide or coach. The source of the design estimation problems explored using the strategies in Table 3 are more likely to be taken directly from the students' design projects. The activities listed previously in Table 2 might be used as a warm up for these more challenging design elements.

Table 2: Strategies for mentoring capstone design project teams to prepare better estimates

- "Spend time explaining to students the role of analysis, prediction, and estimation in the design process, emphasizing concepts like 'it helps us save time, as compared to build and test' and 'it shows that we actually understand the design concept' and 'if test does not agree with analysis, it means we probably don't understand the design and how it actually works'. In short, help them understand motivation for simple estimation and predictive calculation."

- "We often need to coach students about possible formulaic approaches where they may not have or there may not be previous experience."
- "Computers today and many calculators on the internet make iterative solutions more straightforward for students. They need to be encouraged to make some mistakes and coached to make some guesses."
- "It's important that we check results and tell students to have other students on the team also check calculations."
- "We do not currently have a 'set of exercises' in our Capstone course but rely more on each team coach to assist team members in developing this skill [estimation] based on the nature of the industrially sponsored project that the team is working on. … Mentoring has been our most fruitful activity to help the students reach the outcome."
- "At the start of the course, identify the important quantitative values to be calculated for the primary technical areas of the team's design project, then assign one calculation per student to be completed as an informal 'back-of-the-envelope-calculation'. As a twist, give each student an actual business-sized envelope on which to do the calculations, thus limiting how much the students can write/calculate, emphasizing the intent of rough initial calculations, and adding an element of humor."
- "Prior to the detail design phase, I have my students produce a preliminary manufacturing plan. Prior to creating this deliverable, we do an in-class exercise to develop a manufacturing plan for an Automatic External Defibrillator (AED). For this activity, I provide them the sales volume, a Bill of Materials, the sequence of manufacturing operations, and the processing time for each fabrication or assembly element. Once they estimated the available production hours, the takt time for the product can determined and the staffing and number of parallel processes can be determined. Armed with this information, they can use their engineering economy techniques to determine capital investment and payback period."

4 VIGNETTES

The following two vignettes offer a humorous look at estimation. The first is advice from a capstone design instructor to his students and the second is a story from an actual industry experience.

Killer Advice with a Smile

"Really, you can't do it on the back of the envelope?

1. *What are you trying to solve? Sketch the answer that you're looking for! Is it a pressure distribution, a deflection, a stress, a temperature profile? Describe and think carefully about the result that you're trying to get!*
2. *Do some orders-of-magnitude analysis (can the problem be simplified?) What would be lost in the analysis?*
3. *Do not quit... Computers suck, all problems are electrical. Sharpen your pencil, relax.*
4. *What can be learned from boundary conditions? Can the sketch be improved by considering the boundary conditions? Re-sketch what you're looking for.*
5. *When in doubt, differentiate.... If that doesn't work, integrate.*
6. *Small angles, Taylor series, and neglect higher order terms.... Still not working?*
7. *Conserve energy! This simple trick often provides a new solution path to the problem! Invoke thermodynamic considerations for everything! Make the problem as simple as possible.*
8. *F=ma, you can't push a rope, everything else is magic.*
9. *Units, scale, and the size of things... Is your sketch dimensionally correct? Are the equations dimensionally homogenous?*
10. *Really, you can't do it on the back of the envelope?*
    a. *go do it in Excel*
    b. *return to 1"*

Estimation in Industry

"Pratt and Whitney sells thrust. The gas turbine engines they produce are complex machines that produce the thrust. Years ago Pratt & Whitney engineers were trying to solve a pesky issue where compressor vanes (non-rotating airfoils) were buckling due to radial compressive loads. Buckling is a highly nonlinear problem where a slender column under a compressive load eventually becomes unstable and collapses. Design engineers and structural engineers were called in to analyze the problem and find a remedy. A finite element model was developed to simulate the airfoil; however, the lead design engineer and the lead structural engineer were at odds over how to model the loads on the airfoil during the onset of buckling. The structural engineer insisted that airfoil should be modeled in pure compression, while the design engineer insisted that pure compression was not possible. After many days of arguing the point, a meeting was held. The structural engineer and his subordinates were on one side of the table, while the design engineer and his subordinates were on the other. Neither could make a convincing case for their argument. Finally, the design engineer took out a sheet of paper and rolled it into a tube. He placed the tube between his palms and squeezed his hands together until the tube crumpled. He then took out his pencil and began pointing to the bulging areas of the crumpled tube and said the word "tension," and alternatively pointing to the indented areas and said the word "compression." Around the table, heads began to nod and structural analysts agreed with the designer. Sometimes one doesn't even need to write anything down to have an effective analysis."

5 SUMMARY AND NEXT STEPS

This paper highlights the importance of design estimation skills in capstone design courses and brings attention to the fact that students are not learning estimation skills in prior coursework. Estimation is also important for accreditation given that estimation skills connect with nearly half of all ABET outcomes (a,b,c,e, and k).

We anticipated finding a large collection of activities and strategies in the literature, but instead our search results emphasized the lack of resources in the literature for techniques to improve these skills in our students. While the literature review yielded additional suggestions beyond those cited above, many of these others are not from engineering, or are not related to design.

We reached out to our colleagues in the capstone design community to learn about specific activities and mentoring strategies they use to cultivate these skills in their capstone students. These activities are summarized in this paper, but we realize this is a largely untapped resource. We are eager to collect and disseminate more, perhaps as part of the nascent Capstone Design Hub, an online repository of resources for the capstone design community (www.capstonedesignhub.org).

"Estimating is something we get better at the more we do it!"

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215 IMPLEMENTATION OF A NEW TEACHING-LEARNING SYSTEM IN THE BENG DEGREE IN MECHANICAL ENGINEERING TOWARDS ITS EHEA ADAPTATION

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ABSTRACT

As a first stage towards the implementation of the new European Higher Education Area (EHEA) degrees, the School of Design Engineering (ETSID) at the Universitat Politècnica de València (Spain) developed, during 2009-2010, a pilot experience in the first year of the Bachelor Engineering (BEng) degree in Mechanical Engineering. The guidelines of this innovative experience were defined in accordance with the EHEA approaches.

Positive academic outcomes found in this pilot group encouraged to extend this experience to a group of the second year of this BEng degree during 2010-2011. Beside the above mentioned action lines, in this second pilot experience, a similar teaching-learning methodology for the classroom activities was designed for all the core subjects with the aim of improving student performance, so that acquisition of generic and specific competences could be assured.

Classroom activities were designed, so that collaborative work was promoted. In coordination with these activities, autonomous tasks were also developed. In addition, a formative assessment that took into account both classroom and autonomous activities, were implemented in this pilot group.

Keywords: classroom activities, autonomous activities, formative assessment, EHEA adaptation.

1 INTRODUCTION

As a prelude towards the establishment of the EHEA adapted degrees [1] [2] in the School of Design Engineering (ETSID), a pilot experience was developed during academic year 2009/2010 in the first year of its bachelor Engineering (BEng) degree in Mechanical Engineering, according to the following guidelines [3]:

- To implement a new teaching-learning system, based on active methodologies and formative assessment [4].
- To improve the acquisition of knowledge, abilities and competences of students.
- To enhance horizontal coordination of this course by reorganising its subjects contents.

Academic performance of the students taking part in this innovative experience was assessed by means of different rates that were defined for every subject, degree and student [5]. The analysis of these rates led to the following main conclusions:

- Active participation of students in their learning process together with a formative evaluation of their progress result in a considerable improvement of all these rates.
- Implementation of teaching methodologies that enhance active and autonomous learning of students, such as those followed in this pilot group, promotes their greater engagement.
- Furthermore, student success is improved in this pilot group with regard to the other groups of the same year and degree.

These positive academic outcomes encouraged the extension of this innovative experience to the second year of the BEng degree in Mechanical Engineering during academic year 2010/2011. Beside the above mentioned guidelines, in this second pilot experience, interest was focused on the improvement of student academic performance and learning. Thus, classroom and autonomous activities were designed so that the acquisition of generic and specific competences associated to this BEng degree could be assured.

2 DESCRIPTION

This second pilot experience was designed according to the following main objectives:

- To apply collaborative work activities [6]-[8] under the supervision of teachers during classroom sessions.
- To design activities to be performed after class hours that promote students autonomous work.
- To perform a formative assessment [9] that takes into account both classroom and autonomous activities.
- To provide the core subjects of the second year of this degree, with a common teaching-learning methodology that enhances horizontal coordination between these subject matters. Such a coordinated program results in a methodological homogeneity, whereby it is intended to promote student academic performance.

In order to achieve these objectives, the following methodologies were developed. On one hand, classroom activities were organised as collaborative work activities. Students, divided into small groups (3-4 students), solved cases, exercises, problems, etc. previously raised by teachers, and under their supervision. At the end of the class, these activities were collected for their evaluation and subsequent feedback.

On the other hand, during the course, autonomous activities were also designed in every subject matter. These activities were evaluated using different assessment strategies: “one minute papers” in the classroom; on-line through the web of the University; by submission and presentation of the students’ works.

This innovative experience was carried out in one of the three groups of the second year of the BEng degree in Mechanical Engineering at ETSID. 15 teachers took part in this pioneer experience, which involved the following core subjects:

- Elasticity and Strength of Materials
- Fluid Mechanics Engineering
- Thermal Engineering
- Mechanics and Theory of Mechanisms
- Statistical Methods
- Mechanical Technology

Furthermore, 55 students took part in this innovative experience. All these students were only enrolled in second year courses and all of them were previously students of the first year pilot group. During the first week of the academic year, students signed a learning contract [10], whereby they take the responsibility for their own learning and commit themselves to regularly attend all the courses, just as they already did the previous year [3].

3 METHODOLOGY

This innovative experience started in May 2010. First, teachers taking part in this pioneer experience designed an academic calendar consistent with a formative assessment model that included a final retake at the end of every semester [3] (January 2011 for the first semester and June 2011 for the second semester).

During May-July 2010, teachers reorganised the contents of each subject in order to fit the new teaching-learning methodology. During this period, teachers also programmed both, classroom and autonomous activities, of every subject, according to the academic calendar of this pilot group. The corresponding teaching material was then also prepared.

On the other hand, appropriate assessment strategies were designed and programmed for every activity of every subject, as well as their weighting in the final grade (Table 1). In any case, classroom and autonomous activities had at least a 40% weighting in the final grade of the subject under consideration. Furthermore, at least three different evaluation methods were employed in all the subjects.

At the beginning of the academic year (September 2010), the first coordination meeting took place, in which it was decided that subsequent follow-up meetings would be performed every two-months.

TABLE 1. Subjects assessment in the pilot group of the second year of the BEng in Mechanical Engineering.

Assessment methods	Elasticity and Strength of Materials	Fluid Mechanics Engineering	Thermal Engineering	Mechanics and Theory of Mechanisms	Statistical Methods	Mechanical Technology
Oral exam		10%				
Written exam	2x20%	2x25%	3x20%	2x20%	2x35%	2x30%
Test	20%	15%	20%	20%	20%	
Report	10%	15%	20%	10%	10%	15%
One minute paper	10%			10%		15%
Portfolio				5%		
Project work		10%				
Data recording	20%			15%		10%

At the end of the academic year (July 2011), an individual curricular evaluation was carried out. A final analysis of the academic results was then performed, from which conclusions were drawn. Such conclusions were taken into account for the implementation of the corresponding EHEA adapted degree in Mechanical Engineering, during academic year 2011/2012.

4 RESULTS

Teachers taking part in this innovative experience were personally asked about their opinion on this experience both during the follow-up meetings and the final meeting. Moreover, at the end of the academic year, teachers were also asked to complete a survey, so that their agreement with this experience could be assessed (Table 2).

TABLE 2. Teachers survey of the pilot group of the second year of the BEng in Mechanical Engineering.

Question	Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
Do you think that compulsory attendance has improved learning outcomes?	20%	20%	40%	20%	0%
Do you think that with 50-60 students, classroom activities allow individual learning to be adequately fulfilled?	0%	20%	0%	53%	27%
Do you think that weekly evaluation (formative assessment) in other subjects has an adverse effect on your subject?	20%	20%	0%	40%	20%
Do you think that 2-3 written examinations of other subjects taken during class hours are prejudicial to your subject?	27%	33%	40%	0%	0%
Do you think that weekly evaluation should only be retaken by means of evaluation strategies covering larger contents?	0%	60%	20%	20%	0%
In case 2-3 written examinations are performed in some subjects, do you think it is necessary to previously establish a schedule for them?	47%	13%	33%	0%	7%

Answers to the first question indicate that 40% of the teachers think that compulsory attendance of students proves to be important for improving their learning. On the other hand, 80% of the teachers think that with 50-60 students, it is not possible to appropriately fulfill individual learning by means of regular (weekly, fortnightly) assessment strategies. Concerning evaluation, 60% of the teachers think that, in case 2-3 written examinations are taken as part of a subject evaluation, a schedule should be previously established, in order to do not cause disruptions to other subjects. In contrast, performing weekly evaluation as part of a subject assessment has not any adverse effect on other subjects.

Furthermore, in order to analyse the academic performance of this innovative experience, the following rate in terms of the number of European Credit Transfer System (ECTS) was determined for every student:

$$\text{Success rate (S)} = \frac{\text{n}^{\text{o}}\ \text{pass ECTS}}{\text{n}^{\text{o}}\ \text{enrolled ECTS}} \text{x}100$$

Table 3 displays the percentage of students with a given success rate. Results show that the students' success in the second-year pilot group is similar to that of the first year. Moreover, the dropout rate has been reduced to less than half of that corresponding to the first-year pilot group.

TABLE 3. Academic performance of the pilot groups of the BEng in Mechanical Engineering.

Success rate (S)	1st year	2nd year
S = 100%	54%	45%
100% > S ≥ 75%	15%	24%
75% > S ≥ 50%	6%	5%
50% > S ≥ 25%	2%	10%
25% > S > 0%	4%	7%
S = 0%	19%	9%

The academic performance of the students of this pilot group was later compared to that of the students of the rest of the groups of the same year and degree (Table 4). Results reveal an improvement in the students' success of the pilot group with regard to that of the other groups. In particular, 69% of the students of the pilot group passed more than 75% of their enrolled ECTS, compared with 43% of the students of the other groups. Furthermore, while 41% of the students of these groups passed less than 50% of their enrolled ECTS, only 26% of the students of the pilot group failed to pass these ECTS. These results confirm that actions undertaken both in the classroom and autonomous activities are adequate for improving students' learning and academic performance.

TABLE 4. Academic performance of the second year of the BEng in Mechanical Engineering.

Success rate (S)	Pilot group	Other groups
S = 100%	45%	24%
100% > S ≥ 75%	24%	19%
75% > S ≥ 50%	5%	16%
50% > S ≥ 25%	10%	16%
25% > S > 0%	7%	10%
S = 0%	9%	15%

5 CONCLUSION

With regard to students, results indicate that this innovative experience has contributed to improve their learning.

Concerning teachers, this innovative experience has involved a major effort of organization, follow-up and preparation of adequate educational and assessment material. However, this effort has proved to be a positive and rewarding experience due to the satisfactory academic performance of the students of this pilot group.

Moreover, from the analysis of the results of this innovative experience, the following recommendations can be drawn:

- It should be convenient to program a week at mid-semester for assessment examinations taken during the year and counting towards the final grade.
- It should be desirable that classroom activities would be carried out with 25-30 students maximum, in case active methodologies involving full participation of students are implemented.

6 ACKNOWLEDGEMENTS

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216 COMPARATIVE ANALYSIS OF STUDENTS PERFORMANCE IN PRE-EHEA AND EHEA STRUCTURED BENG DEGREES IN INDUSTRIAL DESIGN ENGINEERING

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ABSTRACT

Over the last years, European universities have executed several reforms to implement the changes required within the Bologna process. The teaching-learning system has changed from a teacher-centred model to a student-centred one. This change has provided the opportunity to create a more active and dynamic teaching-learning process with more personalized educational and evaluation methods.

This paper provides a case analysis of the consequences of such change in the academic results of the Bachelor Engineering (BEng) degree in Industrial Design Engineering of the School of Design Engineering ETSID (Universitat Politècnica de València, Spain). The study aims to compare various performance and success rates between first grade students of the European Higher Education Area (EHEA) adapted programme and those obtained by the first grade students of the corresponding pre-EHEA programme at ETSID. The rates used for this comparison have been defined with the aim of having the most objective starting point for this assessment. This study is therefore intended to work as an instrument to monitor the development and effectiveness of different teaching-learning policies, thus contributing to the continuous process of educational improvement at ETSID.

Keywords: EHEA adaptation, student-centred model, Industrial Design Engineering

1 INTRODUCTION

In general, design is an activity that emerges in response to functional and symbolic needs of people and contributes to social well-being. The specificity of product design lies in its "constructive" dimension, which implies materializing ideas in objects that share our habitat. Thus, Industrial Design Engineers are involved in the design of products as well as in resources management and the economic use of technology to produce quality goods and services for society. Almost everything that touches daily life is designed and manufactured.

The overall objective of the Bachelor Engineering (BEng) degree in Industrial Design Engineering is to train professionals with technical and scientific skills to manage the whole production process of products, with a special focus on innovation in a global context.

Moreover, design brings together technological, economic, functional and stylistic dimensions that finally result in a wide variety of products in terms of scale, type and nature. This confluence of different fields in design activities generates a clearly multidisciplinary professional profile that basically combines humanistic sensitivity with scientific and technical knowledge [1].

For this reason, unlike most traditional Engineering degrees, the BEng degree in Industrial Design Engineering involves multidisciplinary training that includes both technological and socio-cultural contents as a part of the fundamental courses of its syllabus. From the first year of this degree, it is convenient that students develop creativity, pragmatism and drawing skills together with scientific and technical knowledge, as well as abstract comprehension, analysis and synthesis skills.

The School of Design Engineering (ETSID) of the Universitat Politècnica de València (Spain) offers its BEng degree in Industrial Design Engineering for over twenty years. Recently, this BEng has been reviewed in order to fit the requirements of the European Higher Education Area (EHEA) [2] [3]. This adaptation process has led to a new programme for this BEng degree based on profile, learning outcomes, competences and student workload. Furthermore, this has implied a change of paradigm in the teaching-learning process: from teacher-centred to student-centred teaching, learning and assessment, in which teachers act as facilitators and guides, and students, in turn, play an active role and take the responsibility for their learning [4] [5]. This has resulted in the incorporation in this new degree of teaching and assessment approaches that highlight active and dynamic learning and that allow students to acquire the desired competences [5]-[9].

This paper provides an analysis of the consequences of such change in the academic results of the BEng degree in Industrial Design Engineering at ETSID. The study aims to compare academic performance between first grade students of the EHEA adapted programme, with those obtained by the first grade students of the corresponding pre-EHEA programme at ETSID. Therefore this study is intended to work as an instrument to monitor the effectiveness of different teaching-learning strategies, thus contributing to the continuous educational improvement process at ETSID.

2 DESCRIPTION

In 2009/2010, the School of Design Engineering (ETSID) of the Universitat Politècnica de València (Spain) implemented the first year of its EHEA structured BEng degree in Industrial Design Engineering. In accordance with the EHEA requirements, in this new degree a variety of active learning methodologies [5]-[8] were incorporated in combination with traditional lectures. In particular, a more significant use of tutorial, cooperative work and project-based learning was noted in this EHEA adapted degree (Figure 1). On the other hand, the use of written examinations and tests was reduced while different formative evaluation strategies [9] were increasingly applied in this new degree like the report, the one minute paper, self evaluation, project work, case work and data recording (Figure 2).

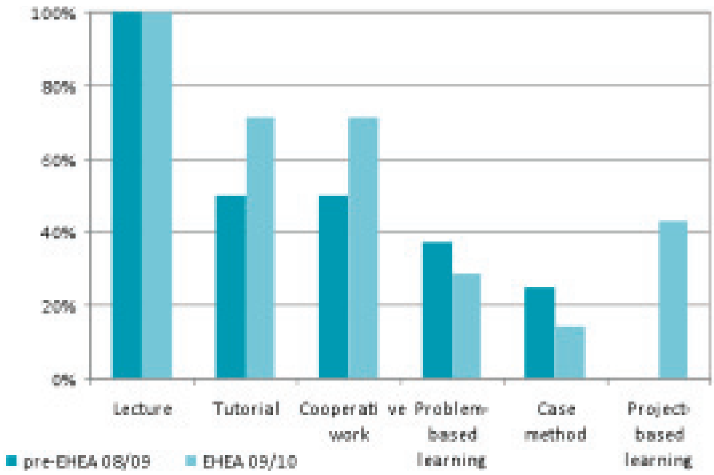

FIGURE 1. *Teaching methodologies in the first year of the pre-EHEA and EHEA structured BEng degrees in Industrial Design Engineering at ETSID.*

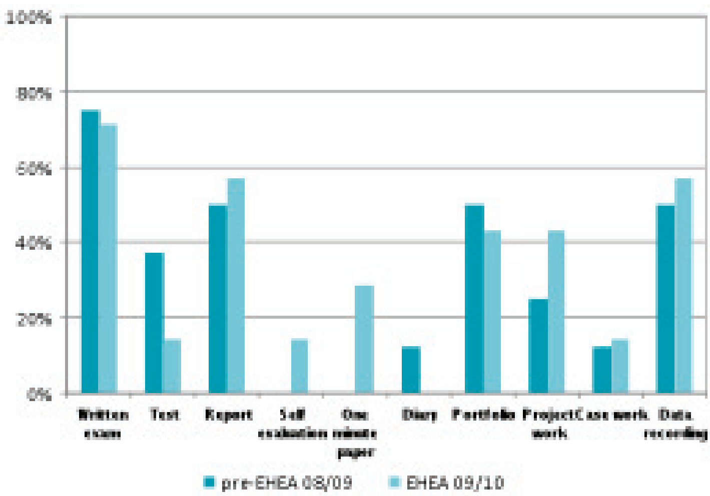

FIGURE 2. *Assessment strategies in the first year of the pre-EHEA and EHEA structured BEng degrees in Industrial Design Engineering at ETSID.*

The aim of this study is to compare academic performance of first year students of the EHEA adapted programme during 2009/2010, with those obtained by the first year students of the corresponding conventional pre-EHEA programme during the previous academic year 2008/2009.

This detailed analysis has been performed on the basis of various rates that have been defined for every core subject:

$$\text{Exam attendance rate} = \frac{\text{n° students who take the exam}}{\text{n° enrolled students}} \text{x100} \qquad (1)$$

$$\text{Performance rate} = \frac{\text{n° pass students}}{\text{n° enrolled students}} \text{x}100 \qquad (2)$$

$$\text{Success rate} = \frac{\text{n° pass students}}{\text{n° students who take the exam}} \text{x}100 \qquad (3)$$

Furthermore, student success in terms of the number of enrolled credits according to the European Credit Transfer and Accumulation System (ECTS) has been determined as well for every student in both BEng degrees:

$$\text{Student success rate} = \frac{\text{n° pass ECTS}}{\text{n° enrolled ECTS}} \text{x}100 \qquad (4)$$

These rates have been calculated for 138 students enrolled in the first year of the EHEA programme of the BEng degree in Industrial Design Engineering, and for 181 students enrolled in the first year of the corresponding pre-EHEA programme.

3 RESULTS AND DISCUSSION

3.1 Subject results

Initially, academic performance of students of the BEng degree in Industrial Design Engineering has been analyzed for every subject. The exam attendance rate, performance rate and success rate have been determined for every core subject in the first year of both the pre-EHEA (Table 1) and EHEA structured (Table 2) degrees.

TABLE 1. Exam attendance rates, performance rates and success rates in the first year of the pre-EHEA structured degree during 2008/2009.

Subject	Exam attendance rate	Performance rate	Success rate
Physics	65%	56%	86%
Mathematics	74%	59%	81%
Material Science	57%	46%	81%
Engineering Design I	83%	69%	83%
Engineering Design II	85%	77%	92%
Drawing	90%	74%	82%
Fundamental Design	88%	88%	100%
Computer Science	87%	73%	84%

TABLE 2. Exam attendance rates, performance rates and success rates in the first year of the EHEA structured degree during 2009/2010.

Subject	Exam attendance rate	Performance rate	Success rate
Physics	84%	69%	82%
Mathematics I	78%	71%	91%
Engineering Design I	77%	75%	98%
Engineering Design II	82%	79%	97%
Drawing	84%	73%	87%
Fundamental Design & Creativity	88%	88%	100%
Computer Science	69%	69%	100%

In the EHEA adapted degree, the implementation of a student-centred approach together with compulsory attendance to classroom/laboratories activities has led to an increase of both the exam attendance rate and the performance rate of scientific subjects (like Physics and Mathematics). In contrast, design related subjects display similar values of these rates in both degrees. These results indicate that changes in the teaching-learning system mainly influence the academic performance of scientific subjects rather than that of humanistic subjects, with traditionally better academic results in this BEng degree.

On the other hand, the success rate of most of the first year subjects has been improved in the EHEA structured degree with regard to the corresponding pre-EHEA degree. The incorporation of active methodologies together with formative assessment strategies has increased the average success rate from 86% in the pre-EHEA degree to 94% in the EHEA degree.

A closer inspection of the grades obtained by the first year students of both degrees reveals that not only the number of students who failed or dropped out has, in general, diminished, but also that students have passed the courses with better grades, as shown by the increasing number of A and B grades in the EHEA degree compared with the corresponding pre-EHEA degree (Figures 3 and 4). This result suggests that the combination of a detailed monitoring of students progress by means of formative assessment strategies and their active participation during courses promotes the quality of the teaching-learning process.

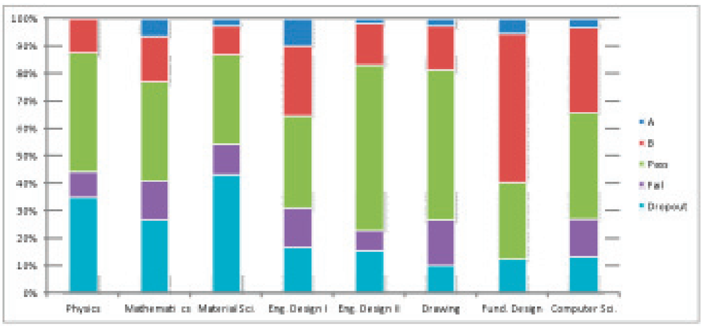

FIGURE 3. *Grades in the first year courses of the pre-EHEA structured BEng degree in Industrial Design Engineering at ETSID during 2008/2009.*

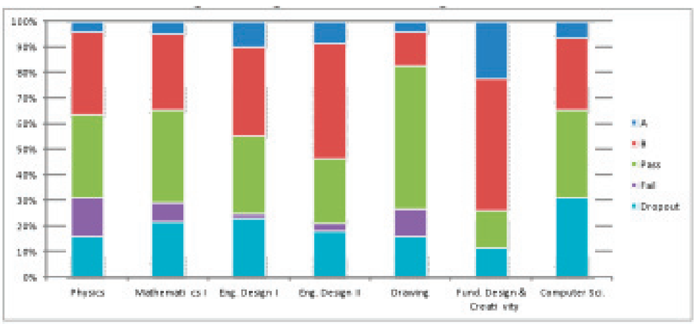

FIGURE 4. *Grades in the first year courses of the EHEA structured BEng degree in Industrial Design Engineering at ETSID during 2009/2010.*

3.2 Student results

In order to complete the analysis of the academic performance of the pre-EHEA and EHEA degrees, the percentage of students as a function of their success in terms of ECTS has been determined as well for the first year of the pre-EHEA (Figure 5a) and EHEA structured degrees in Industrial Design Engineering at ETSID (Figure 5b).

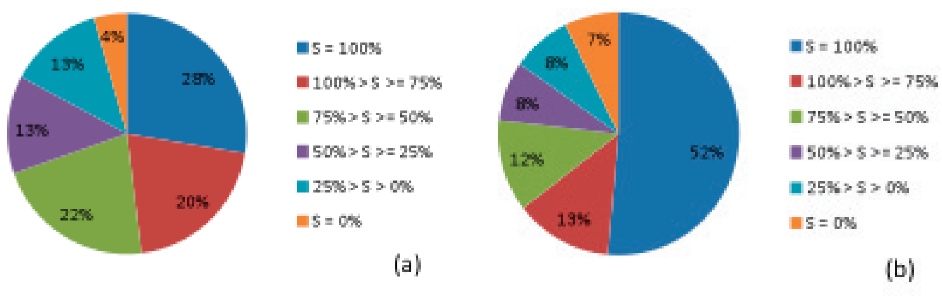

FIGURE 5. *Student success (S) in the first year of the (a) pre-EHEA and (b) EHEA structured BEng degrees in Industrial Design Engineering at ETSID.*

100% success for a given student means that this student has passed all the subjects of which this student has taken the exams. Results display that while 52% of the first year students of the EHEA structured degree exhibited 100% success, just 28% of the students of the corresponding pre-EHEA degree passed all the subjects they intended to. Furthermore, whereas 30% of the students of the pre-EHEA structured degree passed less than half of their enrolled ECTS, only 23% of the students of the EHEA structured degree failed to pass these ECTS. This significant improvement of the student success in the first year of the EHEA structured degree confirms the suitability of the teaching and evaluation strategies that have been implemented in this new degree.

On the other hand, 0% success corresponds to the dropout percentage. Results reveal that for both the pre-EHEA and the EHEA structured degrees, the dropout percentage is similar and equal to 4% and 7%, respectively. This indicates that in the first year of the degrees under study, dropout seems to be independent of the teaching-learning methodologies that have been employed. Similar results have been obtained in previous EHEA adaptation experiences in other BEng degrees at ETSID [10]. It will be therefore convenient to analyse in more detail these results, in order to propose some alternative strategies to diminish this rate in new EHEA structured degrees.

4 CONCLUSION

The keys to the EHEA adaptation lie in the qualitative changes that should be introduced in the teaching-learning process. This has moved from a teacher-centered model to a student-centred model which aims to highlight student participation and commitment. For this reason, it is convenient to assess the impact of these methodological changes in the academic performance, in order to identify and promote the best possible educational practices.

This paper has provided a case analysis of the consequences of such changes in the academic results of the first grade students of the EHEA adapted BEng degree in Industrial Design Engineering at ETSID and those obtained by the first grade students of the corresponding pre-EHEA degree. This comparative analysis has been performed on the basis of different rates that have been defined for every subject and student.

In general, results have proved that active participation of students in their learning process together with their formative evaluation lead to an improvement of the success rates of most of the subjects. Furthermore, the implementation of teaching methodologies that promote active and dynamic learning of students, such as those followed in the EHEA structured degree, contributes to their greater engagement. As it has been shown, this has resulted in an increase of the academic performance in scientific subjects rather than in humanistic ones, with traditionally better academic results in this degree.

Moreover, it has also been found that the implementation of a student-centred approach enhances the quality of the teaching-learning process, as proved by the better grades of the first year students of the EHEA adapted degree.

On the other hand, the analysis of the student success rate has revealed that personal success in this new degree has been considerably improved as a consequence of the incorporation of active methodologies and formative assessment strategies. Furthermore, it seems that the dropout percentage is not directly related to the teaching and assessment strategies. In consequence, it has been suggested to further analyze this result, in order to propose some improvement strategies.

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218 INNOVATIONS TO PRODUCT, CO-OPERATION BETWEEN INNOTOOLS AND SAIMAA UNIVERSITY OF APPLIED SCIENCES

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ABSTRACT

Innotools is a small innovative company placed at Imatra. Company has developed and is manufacturing electrostatically charged stickers, which are competing successfully with 3M yellow glue base stickers. Worldwide markets for these kind of products are about 10 000 millions € /year. Markets showed demand for more developed, coated products, which could be printed and used in several marketing and education (e.g. flipchart) purposes.

Innotools took contact with Saimaa University of Applied Sciences to find expertise in coating. SUAS had this knowledge and research laboratory, so co-operation started. After two years co-operation in research, Innotools developed coated, patented product, which is accepted by global international companies like Cannon. Product will be in the market 2012. Patenting procedure started in the beginning of project.

Three students have made their final thesis work on this subject and one 10 person laboratory course was working to develop Innotools products. Innotools is hiring more employees steadily so this co-operation made it possible to get employer and possible employees to get to know to each other's. A market prospect for new products is huge, so co-operation will continue.

Keywords: Innovation, product development, inquiry-based learning.

1 INTRODUCTION

1.1 Saimaa University of Applied Sciences

Saimaa University of Applied Sciences (SUAS) is an institute of higher education in Southeastern Finland in the cities of Lappeenranta and Imatra. SUAS have about 3000 students, 200 of them being international degree students.

1.2 Saimaa University of Applied Sciences research and development

The objective for SUAS research and development is to develop new or improved products, production facilities, processes, and services companies in South Karelia. SUAS research and development is demand-and user-driven. SUAS research and development is made by the teachers and students under the leadership of teachers. Research and development are carried out in the following ways: university student theses work made for companies and other organizations, from project jobs and training work by students and the work carried out for broader research and development projects which are mainly carried out by the staff of the university. Laboratory for paper technology at SUAS has been making research work during past years. There have been several publications of which some are based on the work of the students in their final thesis work [1]-[3].

FIGURE 1. *Research environment at SUAS Paper Lab at Imatra.*

1.3 Innotools Ltd

Innotools is producing electrostatic stickers in Imatra. Innotools products are based on an electrical film that can be attached to e.g. walls, windows and doors without glue or any other sticking material. Thin, compact electronic PP (polypropylene) film is loaded with static electricity to adhere to surfaces. Innotools got Innofinland Prize year 2011.

The company's notes can be written with pencil or printed without solvents with UV (ultraviolet) printers. Markets, however, needs product that can be printed with any printing machine or home printer. There have been no coated products that can work in these areas, so far. So, Innotools research target has been to develop coated product that can meet worldwide demand. Innotools took contact with Saimaa University of Applied Sciences to find expertise in coating. SUAS had this knowledge and research laboratory, so co-operation started. TEKES (the Finnish Funding Agency for Technology and Innovation) is funding this project between Innotools and SUAS.

2 LEARNING METHODS

2.1 Problem Based Learning (PBL)

Problem based learning is the learning method, which includes the getting the students to meet practical problems [4]. Depending on the contents of the things to learn it is better when learning takes place with authentic real-world problems, instead of a simple theoretical treatment. Problem-based learning is also found to be desirable from the point of view of understanding, connecting the learning content to data structures in the past, the self-control, to the problem solving capacity, as well as in the planning of self-learning [4].

In problem-based learning it is central to construct, organize and re-define new information on the basis of previously learned. The basic idea of learning is that the aim of the learners is solving of a professional task. The teaching is organized mainly in the form of group work in small groups with the teacher is tutoring. PBL has the idea that in education most important task is not only to learn new information but learn to solve problems creatively.

2.2 Inquiry-Based Learning

Inquiry-based learning learning is based on the dynamic, developing information. The information is variable and a learner acquires knowledge itself [5]. Expertise is not only as one individual's skills, but as a communal knowhow of teams and networks [6]. The future society is knowledge-based, so that a considerable part of the population makes work with information [5]. In the future, there is growing need to solve poorly defined problems in the areas full of information. The necessary data-processing skills and expertise to solve the problems can be practiced already in school. Inquiry-based learning is directed towards understanding and explaining the phenomena. Attention is paid to the key concepts or basic ideas. Learning is not just an increase of information, it is development. The teacher has an important role to lead this process.

The important fundamental learning principles are the following [5]:

- The desire to understand and explain the whole phenomena.
- Outgoing problem-based wondering and seeking for information.
- The point of view is that learning is a problem-solving process.
- Noticing of the own preconceptions.
- Attention to key concepts and major ideas.
- Collaborative sharing of knowledge and construction of expertise.

3 RESEARCH TARGET

Innotools Ltd manufactures static electricity adhering sticker notes and posters. Printed sheets can be used, for example, for posters, inserts, marketing material, education etc.

The use of the products is, however, limited to the UV-printing which don´t use any solvent. The aim of the project was to develop a coated product, which may be printed with all printing methods with wet or dry ink, offset, inkjet, digital printing etc. The extension to all products and printing processes would increase the potential of the markets in many ways. The project objective was to develop, control and optimize the coating method, which can ensure products to huge printing markets.

4 TRIAL ENVIRONMENT AND PROCEDURE

The research work was carried out at the SUAS paper technology laboratory in Imatra. In the laboratory it is possible to make pulp and paper, as well as to coat paper with a laboratory coater. The finished products may be tested with variety of quality tests that allows product development work. Production trials were run at Innotools production machine at Imatra.

Machine is one station coating machine, where it is possible to change station and use four different coating methods.

First, the students were given a target as a commercial paper sample. The sample was coated offset paper. The students were expected to reach same quality level with a coated sticker than with a commercial paper. Course in paper coating technology was started little earlier, so the students had some theoretical background on the matter. Students, however, were expected also to study the theory independently. This was even necessary, in order to find solution to the problem.

The students were divided into groups, which used different coating methods. In the laboratory the students mixed different types of coating materials and coated sticker material using different equipment.

FIGURE 2. *Trials at Innotools coating machine.*

5 RESULTS

As a general rule, the tests failed. Since there are no coated electrostatic posters and labels at the market so far, it was known that the research is very challenging. After the failed tests the students studied literature and discussed with teacher about the results. Tests were continued and progress usually took place. The participants began to understand the importance of different factors to the final result.

From separate groupworks results from two works were interesting enough to be developed furher. After paper technology laboratory course, three students continued to make their final thesis on these subjects. In this case, they were able to continue research work very well with minimal guidance.

Furher work showed that some coating methods could me exluded. Finally, the best method was subsequently tested by production machine. The tests were successful, and the confidence to continue the research work as well confirmed. Product development was continued, and approximately a year later, the product was placed on the market. Turnover expectations are 10-20 million € in five years.

FIGURE 3. *Innotools digital printing products at a shop window.*

6 CONCLUSION

Advantages of the inquiry-based learning method at studying product development work were in this project:

- Allows running a large amount of trial sets without financial risk.
- Students can do practical work, failures increase learning but do not consume any extra resources.
- Demand level at industry and skills level of the students can be compared.
- The students are well motivated to learn.

Possible problems:

- Without adequate basic knowledge or tutoring students might frustrate and not be able to fulfill the task.
- There might not be enough time for in-depth learning, students will frustrate, and no innovations will arise.
- If the task is too demanding and results are weak, also the industrial partner will frustrate.

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220 E-LEARNING: CONTRIBUTIONS FROM THE SCHOOL OF DESIGN ENGINEERING ETSID AT VALENCIA (SPAIN)

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ABSTRACT

Technologies in learning and teaching offer nowadays a great variety of possibilities to facilitate innovation competences in engineering students. The Universitat Politècnica de València (UPV), Spain, has implemented an e-learning Action Plan in order to improve the academic performance of its engineering students. This plan consists in making available through the network a wide range of didactic resources, such as on-line courses, virtual labs, on-line lectures, student orientation guides and problem guides, among others.

This paper presents in detail the contributions from the School of Design Engineering (ETSID) at UPV, as well as their impact in the teaching-learning process. The main statistics of these didactic resources is shown along with the strategies that ETSID has been implementing in order to improve their effectiveness.

Keywords: e-learning, learning object, learning kit, open course ware subject

1 INTRODUCTION

Integration of the Information and Communications Technologies (ICT) in Higher Education is one of the key issues within the creation process of the European Higher Education Area (EHEA). For this reason, the Universitat Politècnica de València (UPV) (Spain) has included as one of the guidelines of its Strategic Plan for 2007-2014, the increasing use of ICT in teaching, as a way to improve the academic performance of its students.

This has led to the creation in 2008 of an e-learning Action Plan at UPV which aims to develop a complete didactic offer based on ICT, including on-line courses, practical exercises, learning forums, and digital documents. As result, an educational platform (named PoliformaT) that integrates different digital teaching materials has been implemented at UPV.

In this paper, contributions of the School of Industrial Design Engineering (ETSID) at UPV to this e-learning Action Plan are analyzed in detail, as well as their impact in the teaching-learning process. The main statistics concerning these didactic resources is shown along with the strategies that ETSID has been implementing in order to improve their effectiveness.

2 LEARNING OBJECTS

The term Learning Object was originally introduced by W. Hodgins in 1992 [1]. One of its most recent definitions has been later stated by D. Wiley in 2000 [1], who considers a Learning Object as any digital resource that can be reused to support learning. In this sense, at UPV a Learning Object refers to a minimum learning unit which can be reused and sequenced, with the following characteristics:

- be in digital format
- have a pedagogical purpose
- be interactive
- be an elemental and independent learning unit
- be reusable in different educational contexts

Several Learning Objects can be combined to form a Learning Kit, which is therefore a more complex learning unit. In turn, the combination of different Learning Kits results in an OCW (Open Course Ware) Subject. In general, Learning Objects can be classified into: Polimedias, screencasts, didactic videos, interactive numeric simulations, Virtual Laboratories and Teaching Papers.

In particular, this section is focused on the use of Polimedias, Virtual Laboratories and Teaching Papers at UPV. Figure 1 displays the number of these Learning Objects that have been generated until now at UPV, being most of them Polimedias [2]. 10% of these UPV Learning Objects have been produced at ETSID.

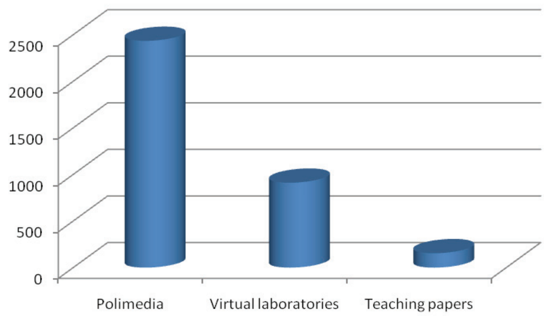

FIGURE 1. *Learning Objects at UPV.*

2.1 Polimedias

Polimedias are Learning Objects consisting of videos where the voice and the image of the instructor are displayed synchronously with a presentation. UPV instructors may learn abilities concerning the filming of these Polimedias by attending specific courses at the UPV Institute of Education Sciences. Figure 2 exhibits the contributions to Polimedias from all the UPV Schools [3], whose acronyms are listed in Table 1. These results indicate that the Schools with a higher Polimedias' production are ETSID, followed by EPSA and EPSG.

TABLE 1. Acronyms of the UPV Schools.

Acronym	School
ETSID	School of Design Engineering
ETSIAplic	School of Applied Informatics (now: School of Informatics Engineering)
ETSMRiE	School of the Rural Environment and Enology (now: School of Agronomy Engineering and Natural Environment)
BBAA	Faculty of Fine Arts
ADE	Faculty of Business Administration
EPSA	Polytechnic School at Alcoy
EPSG	Polytechnic School at Gandia
ETSA	School of Architecture
ETSGE	School of Building Engineering
ETSIA	School of Agricultural Engineering (now: School of Agronomy Engineering and Natural Environment)
ETSIAMN	School of Agronomy Engineering and Natural Environment
ETSICCP	School of Civil Engineering
ETSIGCT	School of Geodesic Engineering, Cartography and Topography
ETSII	School of Industrial Engineering
ETSINF	School of Informatics Engineering
ETSIT	School of Telecommunication Engineering
FI	Faculty of Informatics (now: School of Informatics Engineering)

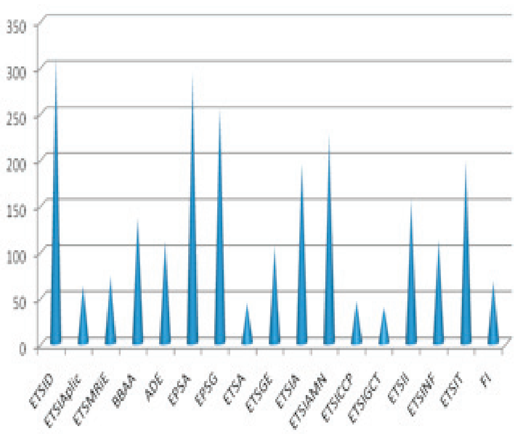

FIGURE 2. *Polimedias' production of the UPV Schools.*

An example of an ETSID Polimedia is shown below (Figure 3): Origin of ETSID (Los Orígenes de la Escuela Industrial) by E. Ballester-Sarrias (available only in Spanish), whose description can be found at: http://riunet.upv.es/handle/10251/1233

This complete Polimedia is available at:

http://polimedia.upv.es/visor/?id=e1e9d3d8-70f3-ff4c-8c9e-bdefdfdd3738.

This Polimedia displays a lecture given by the present Dean of ETSID on the occasion of the first centenary of its foundation, which is one of the lessons of the optional subject "History of Science and Technology" in the Mechanical Engineering, Design Engineering and Electronic Engineering degrees at ETSID.

FIGURE 3. *Polimedia "Origin of ETSID".*

2.2 Virtual Laboratories

Virtual Laboratories are interactive Learning Objects made with Flash, Java (applets), Matlab, Mathematica or other computer programs, that are hosted at a UPV server. Contributions to Virtual Laboratories from the different UPV Schools are displayed in Figure 4 [4]. As it can be shown, production of Virtual Laboratories at ETSID is still limited compared with that of other UPV Schools, especially ETSIT and ETSII. Thus, several courses on "Virtual Laboratories using Easy Java, Mathematica and Matlab" are going to be held at ETSID in the near future, so that the contribution of Virtual Laboratories can be encouraged at our School.

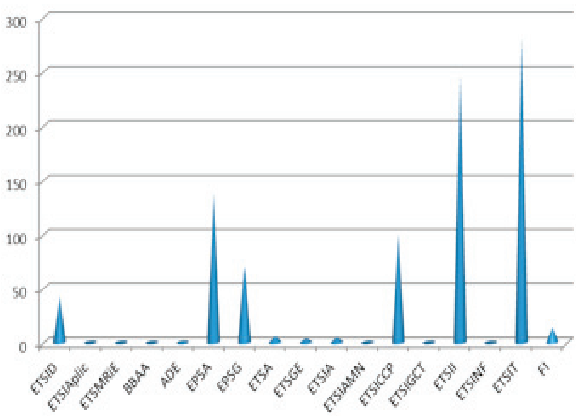

FIGURE 4. *Virtual Laboratories' production of the UPV Schools.*

Figure 5 shows as example the following ETSID Virtual Laboratory: Visualizer of Fraunhofer diffraction patterns in periodic and fractal networks (Visualizador del patrón de difracción de Fraunhofer de redes periódicas y fractales) by M.H. Giménez and J.A. Monsoriu (available only in Spanish) [5]. The description of this Polimedia can be found at: http://riunet.upv.es/handle/10251/9234. This Virtual Laboratory is an applet (performed in Easy Java [6] [7]) that allows users to select the parameters of a fractal network based on a Cantor set, in order to observe the Fraunhofer diffraction pattern in a gray color scale. This applet also displays the diffraction pattern of the equivalent periodic network. On the other hand, this Virtual Laboratory has been successfully complemented with real experiments [8] and later included in the subject "Technology of Optoelectronic Sensors" of the Master Degree in Sensors for Industrial Applications at ETSID.

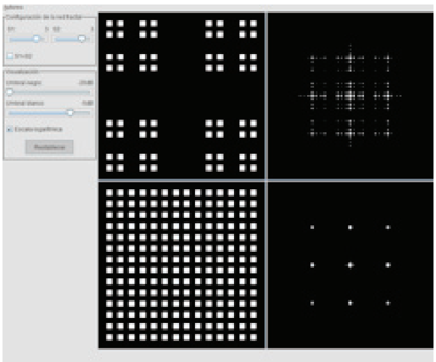

FIGURE 5. *Virtual lab "Visualizer of Fraunhofer diffraction patterns in periodic and fractal networks".*

2.3 Teaching Papers

Teaching papers are Learning Objects hosted in a UPV free repository (RiuNet) (http://riunet.upv.es). Figure 6 displays the contributions to these Polimedias from all the UPV Schools [9]. ETSID ranks in 6th place in the number of Teaching Papers. The best performance is shown by ETSIAMN and ETSA. In order to increase and diversify the production of Teaching Papers at ETSID, the School has planned to organize several informative sessions on this issue. On the other hand, a book collecting Teaching Papers developed at ETSID is currently being prepared.

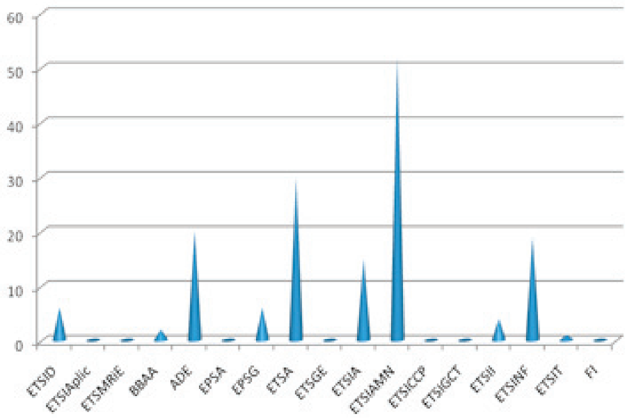

FIGURE 6. *Teaching Papers' production of the UPV Schools.*

An example of an ETSID Teaching Paper is Design of urban elements: drinking fountains (Diseño de elementos urbanos: Fuentes bebederos) by M. Puyuelo and M.D. Merino (available only in Spanish). The description of this Learning Object can be found at: http://riunet.upv.es/handle/10251/13707. This paper deals with the aspects that should be considered for the design of a drinking fountain as urban furniture.

3 LEARNING KITS

Learning Kits are digital units made up of several Learning Objects. Learning Kits should be part of a given subject and are available for students at the UPV PoliformaT platform. In a Learning Kit, its Learning Objects are clustered by means of Coupling Objects, such as methodological guides, activity guides and evaluation tests.

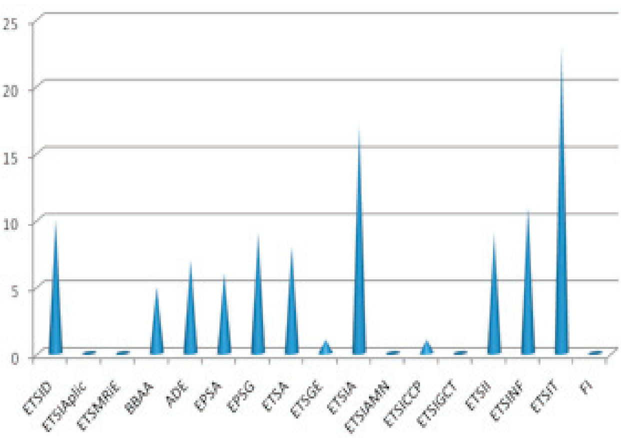

FIGURE 7. *Learning Kits' production of the UPV Schools.*

Contributions to Learning Kits from all the UPV Schools are shown in Figure 7. Results show that the number of Learning Kits produced at ETSID is satisfactory. Nevertheless, a specific course on the use of the PoliformaT platform for the development of Learning Kits is going to be offered at ETSID, in order to further increase the production of these educational materials at our School.

An example of an ETSID Learning Kit is shown below (Figure 8): Processing of experimental data (Tratamiento de datos experimentales) by A. Vidaurre, M.H. Giménez, J. Riera and J.A. Monsoriu (available only in Spanish) [10]. This Learning Kit deals with experimental error processing, its propagation in indirect measurements, the graphic representation of physical quantities and the least square fitting method. It also includes an on-line evaluation test for students.

FIGURE 8. *Learning Kit "Processing of experimental data".*

4 OPEN COURSE WARE (OCW) SUBJECTS

An Open Course Ware (OCW) Subject is a free access on-line collection of Learning Objects and Learning Kits of a given subject. Figure 9 displays the contributions to OCW Subjects from all the UPV Schools. Production of OCW Subjects at ETSID is quite satisfactory, although being not so significant such as that of other Schools, especially ETSINF.

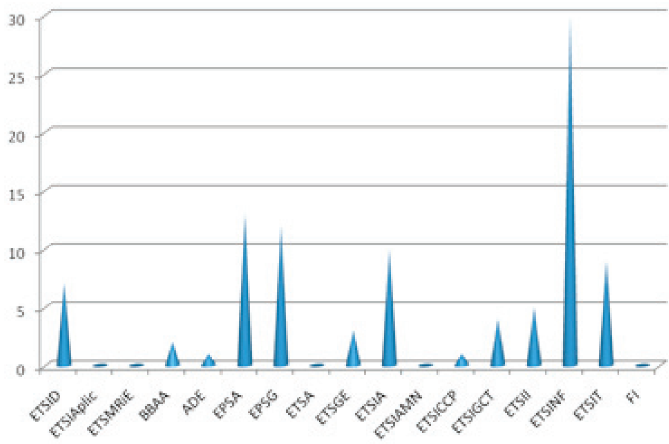

FIGURE 9. *OCW Subjects' production of the UPV Schools.*

An example of an ETSID OCW Subject can be found at:

http://www.upv.es/contenidos/OCW/menu_urlc.html?http://www.upv.es/pls/oalu/sic_asi.OCW_Ramasi?p_rama=T&p_idioma=c&p_vista=MSE

Applications and processes of new materials (Aplicaciones y procesos de nuevos materiales) by J. Orozco and M. Perales (available only in Spanish) is a subject that aims at providing an overview of the use of new materials and their processing in Industrial Design.

It is also worth to point out that ETSID is one of the four UPV Schools that has been awarded with the "Quality Mention to OCW Subjects". However, informative activities among instructors are being intensified at ETSID, to further promote the development of OCW Subjects, especially among those subjects with many Learning Objects.

5 CONCLUSION

Contributions from the School of Industrial Design Engineering (ETSID) to the e-learning Action Plan at UPV have been analyzed in detail. In general, results reveal that, so far, the ETSID participation is satisfactory. Thus, 10% of the UPV Learning Objects, 9% of the UPV Learning Kits and 7% of the UPV OCW Subjects have been developed at ETSID. Furthermore, ETSID is the School with the highest Polimedia production at UPV. Especially noteworthy is also the "Quality Mention to OCW Subjects" that has been awarded to ETSID.

Despite the above results, several actions, such as specific training courses and special informative sessions for instructors, as well as the publication of a book including a selection of Teaching Papers, are being implemented at ETSID, in order to further improve its participation in the e-learning Action Plan at UPV.

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221 FITTING MATHEMATICS TO EHEA IN AEROSPACE ENGINEERING AT THE SCHOOL OF DESIGN ENGINEERING ETSID IN VALENCIA (SPAIN)

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ABSTRACT

As most European universities we are immersed in the modification of all curricula in order to conform to the European Higher Education Area (EHEA). This adaptation process is carried out at all levels, from universities, study programmes to each particular subject. We will approach how we have faced these changes in the Mathematics subject of the first year of Aerospace Engineering at the School of Design Engineering ETSID (Universitat Politècnica de València UPV, Spain). Mathematics has suffered a notable reduction in the number of credits despite the fact that the objectives and contents to be reached are very similar. The most important change in teaching methodology is encouraging autonomous work to be taken by the students which makes instructors to keep a continuous track of student's performance.

UPV started to build up a platform known as PoliformaT, which has partially been used by the authors since 2007. Nowadays its use includes organization of computer aided classes, settlement of student's work and tasks and monitoring his/her work. This effort by teachers and students brings as result an improved performance in the subject. Results obtained are presented in this paper and compared to the ones previously obtained.

Keywords: EHEA, educational platform, Mathematics at Enginnering

1 INTRODUCTION

The Bologna process was designed in Europa with the aim of getting a system of university academic degrees easily recognizable and comparable, and promoting the mobility of students, teachers and researchers aa well as incorporating the European dimension into higher education [1].

Spain engaged this project from the very beginning by establishing the adequate foundations to implement it with professional capacities recognized [2].

In this way the Polytechnical University of Valencia UPV has followed changing process in order to adapt its degrees to this setting. And in particular the BEng Aerospace Engineering degree at ETSID has been transformed from a 5 years degree into a 4 years degree. This has meant a deep transformation of some subjects. One of these subjects is Mathematics which has moved from having 15 credits (10.5 cr. Theory/Problems & cr. 4.5 Lab Practice) to 12 credits (9 cr. Theory/Problems & 3 cr. Lab Practice). Hence Mathematics Lab classes realized with MATHEMATICA [3, 4] have suffered a 1/3 reduction in the number of credits assigned.

Hence using the educational platform known as PoliformaT and developed by UPV from the Sakai educational platform [5], in the last years has smoothened our transition during this last academic year in which we have been obliged to get most of the ICT in order to improve and modernize the learning possibilities of our students. In this paper we will show some of the changes we have taken in the subject and some of the tools that we have used in order to fit it into the new environment.

2 FITTING MATHEMATICS LAB CLASSES TO EHEA

We think that the 1/3 reduction in Mathematics Lab classes – from 90 minutes each week during 2009/10 to 60 minutes during 2010/11-- should not bring out a reduction in the contents covered since Mathematics is a basic subject and all topics treated here are really needed in the student's curricula.

Therefore adaptation cannot be just a temporal one but a comprehensive one:

- The student must work more outside the classroom, and less inside the classroom.
- The teacher must schedule the activities that the students are going to make on their own, so that they can be done independently.
- The teacher must organize the assessment of such activities.

The authors have adapted the contents and the sequencing of the lab sessions with the aim of making this process efficient. So, during this last year the students have been requested to prepare each session by themselves, the corresponding mathematical concepts having been covered in theoretical/practical classes in advance.

With this goal and by means of the Resources tool of Poliformat, the lecturers provide on a weekly basis the material with the information needed so that the students learn to solve the type of exercises to be worked and assessed in the following session.

FIGURE 1. *Resources screen at PoliformaT.*

Thus each student uses his mathematical knowledge achieved in the classroom, the aforementioned instructions and the MATHEMATICA software to do his assignments. In addition they are also given a list of exercises that enable them to practice and check that they have really understood the topic.

During the first 20 minutes of each lab session are able to clarify any doubt that they might have and the lecturer shows the solution of the proposed exercises. During the last 40 minutes the students have to solve a number of exercises provided by means of the Tests & Quizzes tool of PoliformaT.

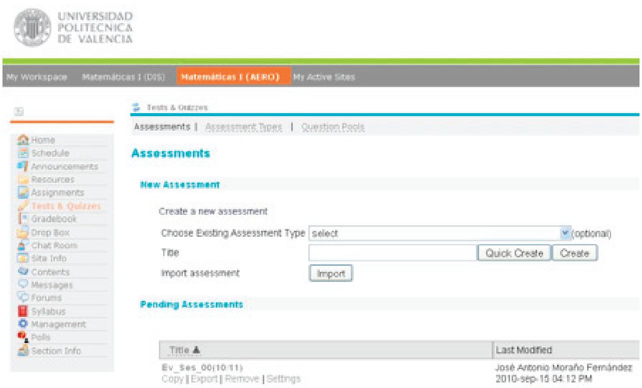

FIGURE 2. *Tests & Quizzes screen at PoliformaT.*

These exercises are to be done individually by each student in the lab classroom while the instructor is available to assist the students that ask for it.

If desired the instructor may control the computer from which each student is doing his work. Fig 3 shows the screen with the IP addresses allowed to interact, as well as the corresponding login, password and time selected for the exercise.

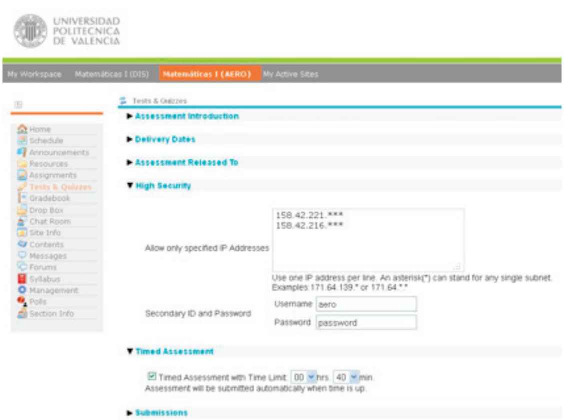

FIGURE 3. *A test setting with PoliformaT.*

All grading results may be automatically uploaded in a 'Gradebook' tool of PoliformaT.

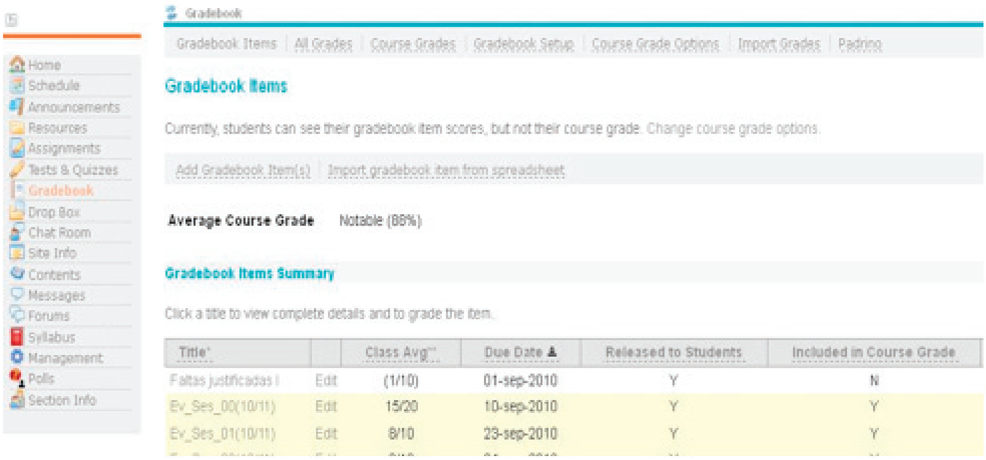

FIGURE 4. *A Gradebook screen with PoliformaT.*

Selecting any session from the Gradebook we are able to see, filter and reorder the marks obtained by the students.

3 MARKS

Table 1 contains the marks obtained by the students during 2009/10, 2010/11 and 2011/2012 (* data up to April 2012) in the lab sessions.

TABLE 1. Lab session marks comparative.

	M1	E1	M2	E2
2009/10	8.2	4.6	8.3	5.7
2010/11	9.4	5.2	8.8	6.5
2011/12	9.6	5.8	9.1*	n/a

In Tab 1, Mi stands for the mean obtained during the weekly sessions in the classroom during semester i where as Ei stands for the mean of the marks obtained by the students in individual exam during semester i. At the time of submitting this paper students have not done the E2. This figure be provided during the conference.

The mean of the weekly sessions and the marks in exams have been constantly increasing (note that since 2010 students prepare the lab sessions beforehand).

4 STUDENTS PERCEPTION

During the course 2009/10 the first two authors consulted the students opinion on different issues in a completely anonymous way by means of the Polls tool [6]. The authors have used this tool again and repeated the same questionnaire during 2010/11. In the following tables we may compare the students' opinions

The first two questions are concerned with the organization of the practices itself. The questions, possible answers and results are shown in the Table 2.

TABLE 2. Perception of students on laboratory practice in general.

Do you think that the number of practices undertaken is adequate to learn the content of the subject?	09/10	10/11
Yes	92 %	73 %
There should be more	4 %	14 %
There should be less	4 %	14 %

Do you think the assessment of laboratory practice in each session fits to the content developed in class?	09/10	10/11
Much	34 %	8 %
Enough	51 %	67 %
Little	15 %	26 %

It is clear that the vast majority of students have thought that practices that had been done were very consistent within the course. Even though we will make later some final comments it may be worthwhile that during 2009/10 we had 90 minutes lab sessions and the students did not have to prepare the sessions in advance and were able to learn about it at class and the authors' opinion is that 2010/11 students have understood the question as whether the each session fits to the content developed during the first 20 minutes when the instructors really referred to the content studied in previous theoretical and problems classes

A second block of questions searched for the opinion of students about the benefits of using the platform in the laboratory practice sessions (Table 4).

TABLE 3. About the use of PoliformaT in laboratory practices.

Using PoliformaT in the laboratory practices:	09/10	10/11
Makes easier to learn the contents of the subject	48 %	48 %
Makes more difficult to learn the contents of the subject	4 %	5 %
Makes no difference in learning the contents of the subject	48 %	47 %

I think that being evaluated in lab practice through PoliformaT at the end of each practice session is good for my learning:	09/10	10/11
Yes, it's good	73%	59 %
No, it is not good	8 %	11 %
I don't know	19 %	30 %

According to the results we see that the students do not have a negative perspective towards the use the platform (4-5% think it may more difficult using it and just 8-11% do not like being evaluated at the end of each session).

The following two questions try to seek the perception of the students on the MATHEMATICA software used and a possible transfer of this form of evaluation to Theory-Problem (Table 4).

TABLE 4. Students'opinion on MATHEMATICA and transferring the method to T/P.

I think that the MATHEMATICA software:	09/10	10/11
Enables to understand better the theoretical part of the subject and I will be able to take advantage from it in the future	79 %	61 %
Is a tool I will use just for calculations	17 %	36 %
Whose learning does not reward, there are other software easier to use	4 %	3 %

Do you think it would be a good option that sessions of Theory-Problems carried out with a PoliformaT test during some day each week?	09/10	10/11
Yes, it would be good	57 %	48 %
No, it would not be a good idea	24 %	25 %
I don't know	18 %	27 %

Teaching in English is a relevant issue at Aerospace Engineering. Thus a final question was raised on this topic (Table 5).

It is worthwhile noting that classes were given in Spanish during 2009/10. However one of the teachers taught in English during the first semester of 2010/11, year in which a high academic performance project was implemented at ETSID with the aim of delivering at least 50% of the whole instruction in English.

TABLE 5. Students'opinion on being lectured in English.

I think that receiving classes in English in 1st year is interesting:	09/10	10/11
Yes	31 %	33 %
No	31 %	22 %
Yes, with a progressive increase to the English teaching	38 %	45 %

Perhaps it should be wise splitting the group into English and Spanish teaching. The fact is that more than 2/3 of students were not happy to receive all the teaching in English from the very beginning versus 1/3 that supported the idea of receiving instruction in English from the very beginning.

5 CONCLUSION

During 2009/10 the students were able to prepare end learn on the topic to be worked out during each session in the first part of the class while during 2010/11 the students have been required to work before each session by themselves.

From the polls realized and the results obtained we find that the opinion on the lab classes has worsened, however we find the paradox that the results and their performance has improved.

Perhaps their impression comes motivated by their feeling that it would be better to learn and work the whole practice in the classroom and be able to solve immediately any doubt they might have. However it seems that this extra work for them has been rewarded in their overall performance. And another possible explanation may be directly related to the different Mathematics level of knowledge when students start their university studies [7].

In Table 2 the students express that the practices are appropriate to the course content and subject. In Table 3 we may see that most students think that makes easier (or there is no difference) to learn the contents of the subject by using PoliformaT, and think that being evaluated in laboratory practice through PoliformaT at the end of each practice session is good for their learning.

Finally, Table 4 shows that students are happy with the mathematical software used and consider a good idea to use the platform in order to improve its understanding of the theory-problem sessions

6 ACKNOWLEDGEMENTS

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224 FUNCTIONING AND DEVELOPMENT OF DISTANCE EDUCATION AT SILESIAN UNIVERSITY OF TECHNOLOGY

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ABSTRACT

This paper presents functioning and development of distance education at Silesian University of Technology based on Distance Learning Platform. Distance Learning Platform is example of a modular object-oriented dynamic learning environment represents LMS (Learning Management Systems) technology, a software package designed to help educators create quality online courses. Currently on Distance Learning Platform at Silesian University of Technology are available over 1600 online courses created for students of thirteen University's faculties. Number of Distance Learning Platform users exceeds 44000. Distance Learning Platform has been working at Silesian University of Technology since September 2005 (http://platforma.polsl.pl). About 20 servers are integrated to one e-learning service for thirteen faculties of the University. Distance Learning Platform is constantly developed. New interesting features are added as new modules to source code. New Platform modules implements the most modern technology appears in web-based e-learning and Internet services. Example of them is: Web 2.0 technology. Majority elements of Web 2.0 technology are currently implemented to Distance Learning Platform.

Keywords: Distance Learning, Distance Education, e-Learning, Learning Management, Internet

1 INTRODUCTION

The Silesian University of Technology, being one of the biggest technical universities in Poland and the first founded in Silesia has successfully been pursuing its mission of education, research and development on the one hand maintaining academic tradition originating from the Lvov Technical University and on the other hand, adjusting itself all the time meets new challenges of the future. The Silesian University of Technology is a big university teaching approximately 30000 of students. The University consists of 13 faculties: Faculty of Architecture, Faculty of Automatic Control, Electronics and Computer Science, Faculty of Biomedical Engineering, Faculty of Civil Engineering, Faculty of Chemistry, Faculty of Electrical Engineering, Faculty of Mining and Geology, Faculty of Energy and Environmental Engineering, Faculty of Mathematics and Physics, Faculty of Mechanical Engineering, Faculty of Materials Science, Metallurgy, Faculty of Organization and Management and Faculty of Transport.

Distance education, or distance learning, is a field of education that focuses on the pedagogy, technology, and instructional systems design that are effectively incorporated in delivering education to students who are not physically "on site" to receive their education. Instead, teachers and students may communicate asynchronously (at times of their own choosing) by exchanging electronic media, or through technology that allows them to communicate in real time (synchronously). Distance education courses that require a physical on-site presence for any reason including the taking of examinations is considered to be a hybrid or blended course or program [4].

Development research on creating integrated distance learning system for Silesian University of Technology was started in 2001, but Internet was practical used in education since nineties. Technical possibilities using Internet in education are in existence since 1991, the year of connection polish academic networks to world-wide Internet. Silesian University of Technology was one of several first polish universities connected to Internet in 1991.

For next years, Internet application in education has been more and more popular, especially at Faculty of Automatic Control, Electronics and Computer Science and other faculties, where using personal computers in education is necessary [5]. For many years systematizing and regularization all activities in distance learning at whole University are necessary. It is the main purpose of Distance Learning Platform at Silesian University of Technology.

2 DISTANCE LEARNING PLATFORM AT SILESIAN UNIVERSITY OF TECHNOLOGY

Development research on creating integrated Distance Learning Platform for Silesian University of Technology was started in 2001, at Institute of Electronics, Faculty of Automatic Control, Electronics and Computer Science. Research on this area was based on:

- testing several application useful for distance learning,
- checking possibilities of adaptation distance learning software to University requirements,
- attempting to choose one (several) of them to construct distance learning service for whole University.

Tested applications can be differed to three categories:

- authoring applications : The web authoring tools, course authoring tools, media editors, content creators - software to creating and integrating e-learning content (courses, web-pages, multimedia files),
- LMS (Learning Management System), web servers, database servers, media servers – software to making e-learning products (courses) available over

a network, hosting, administrating, maintaining, supporting,

- access applications: e-learning client applications, web-browsers, media players, communication tools – software to locating and experiencing e-learning products.

As results of this research Distance Learning Platform was created, as effective, integrated e-learning service for all faculties of Silesian University of Technology. Distance Learning Platform has been working at Silesian University of Technology since September 2005 (http://platforma.polsl.pl). About 20 virtual servers are integrated to one e-learning service for twelve faculties of the University. Individual links to these servers are presented on Table 1.

TABLE 1. Virtual servers of Distance Learning Platform at Silesian University of Technology.

Nr	Destination	URL
1	Silesian University of Technology	http://platforma.polsl.pl
2	Faculty of Architecture	http://platforma.polsl.pl/rar
3	Faculty of Automatic Control, Electronics and Computer Science	http://platforma.polsl.pl/rau
4	Faculty of Automatic Control, Electronics and Computer Science, Institute of Automatic	http://platforma.polsl.pl/rau1
5	Faculty of Automatic Control, Electronics and Computer Science, Institute of Computer Science	http://platforma.polsl.pl/rau2
6	Faculty of Automatic Control, Electronics and Computer Science, Institute of Electronics	http://platforma.polsl.pl/rau3
7	Faculty of Biomedical Engineering	http://platforma.polsl.pl/rib
8	Faculty of Civil Engineering	http://platforma.polsl.pl/rb
9	Faculty of Chemistry	http://platforma.polsl.pl/rch
10	Faculty of Electrical Engineering	http://platforma.polsl.pl/re
11	Faculty of Mining and Geology	http://platforma.polsl.pl/rg
12	Faculty of Energy and Environmental Engineering	http://platforma.polsl.pl/rie
13	Faculty of Mathematics and Physics	http://platforma.polsl.pl/rms
14	Faculty of Mechanical Engineering	http://platforma.polsl.pl/rmt
15	Faculty of Materials Science, Metallurgy	http://platforma.polsl.pl/rm
16	Faculty of Organization and Management	http://platforma.polsl.pl/roz
18	Faculty of Transport	http://platforma.polsl.pl/rt
19	Department of Foreign Languages Learning	http://platforma.polsl.pl/rjm1
20	Silesian University of Technology Library	http://platforma.polsl.pl/rjo1

Currently on Distance Learning Platform at Silesian University of Technology are available over 1600 online e-learning courses. Number of users exceeds 44000. Statistics of each virtual server are presented on Table 2.

Distance Learning Platform works as typically asynchronous e-learning service, but in the future more synchronous e-learning services will be added. The most important features of Distance Learning Platform are:

- Easy creation of courses from existing resources,
- Course content which can be re-used with different learners, including content from other vendors (Blackboard, WebCT etc.),
- User-friendly environment,
- Students enrolment and learner authentication are simple and secure,
- Intuitive online learner and teacher management features.

TABLE 2. Statistics of Distance Learning Platform at Silesian University of Technology.

Nr	URL	Nr of users	Nr of courses
1	http://platforma.polsl.pl	-	-
2	http://platforma.polsl.pl/rar	1872	142
3	http://platforma.polsl.pl/rau	-	-
4	http://platforma.polsl.pl/rau1	2431	258
5	http://platforma.polsl.pl/rau2	4171	374
6	http://platforma.polsl.pl/rau3	2904	181
7	http://platforma.polsl.pl/rib	816	61
8	http://platforma.polsl.pl/rb	1872	65
9	http://platforma.polsl.pl/rch	649	38
10	http://platforma.polsl.pl/re	1917	109
11	http://platforma.polsl.pl/rg	3736	21
12	http://platforma.polsl.pl/rie	2521	46
13	http://platforma.polsl.pl/rms	11182	194
14	http://platforma.polsl.pl/rmt	994	45
15	http://platforma.polsl.pl/rm	949	18
16	http://platforma.polsl.pl/roz	528	5
18	http://platforma.polsl.pl/rt	1310	34
19	http://platforma.polsl.pl/rjm1	5374	70
20	http://platforma.polsl.pl/rjo1	1589	4
		--------	-------
	TOTAL:	**44815**	**1665**

3 FUNCTIONING OF DISTANCE LEARNING PLATFORM

Distance learning systems are sometimes also called Learning Management Systems (LMS), Learning Content Management Systems (LCMS), Virtual Learning Environments (VLE), education via computer-mediated communication (CMC) or Online Education [11]. A Learning Management System (LMS) is a software package that enables the management and delivery of online content to learners. LMS are web-based to facilitate "anytime, anyplace, any pace" access to learning content and administration. The characteristics of LMS include:

- Manage users, roles, courses, instructors, and facilities and generate reports,
- Course calendar,
- Learner messaging and notifications,
- Assessment/testing capable of handling student pre/post testing,
- Display scores and transcripts,
- Grading of coursework and roster processing,
- Web-based or blended course delivery.

Architecture of Distance Learning Platform as a Learning Management System is presented on Figure 1.

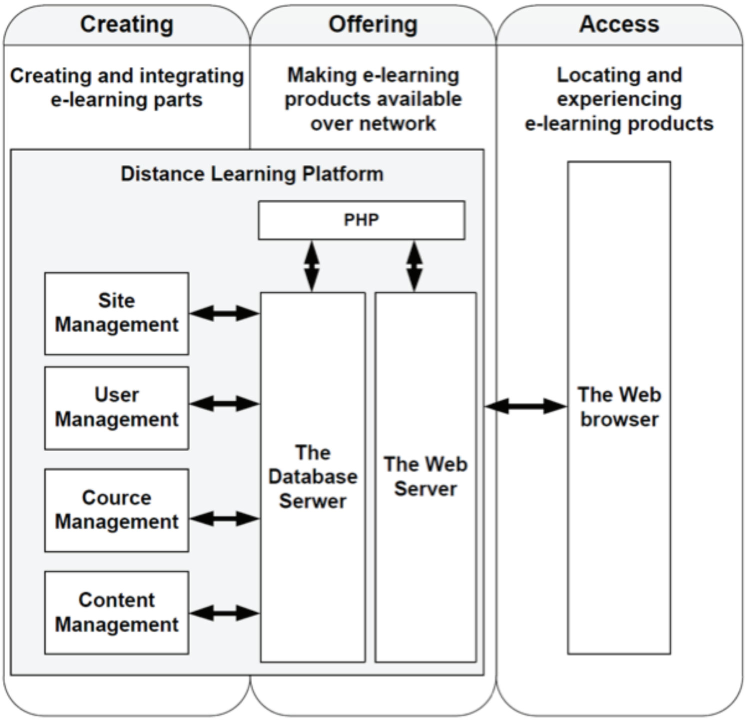

FIGURE 1. *Architecture of Distance Learning Platform*

Distance Learning Platform is based on following software configuration:

- Unix operating system : FreeBSD 8.0-RELEASE [2],
- HTTP Server : Apache v.2.2.22 [1],
- PHP language interpreter v.5.2.17 [3],
- Database server : MySQL v.5.1.55 [3],
- Learning Management System: Moodle v.1.9.9+ [10].

Distance Learning Platform is based on modular object-oriented dynamic learning environment named Moodle (www.moodle.org), represents LMS (Learning Management System) technology, a software package designed to help educators create high quality online courses [6]. Distance Learning Platform runs without modification on Unix, Linux, FreeBSD, Windows, MacOS X, NetWare and any other systems that support PHP, including most webhost providers. Data is stored in a single database: MySQL. Moodle is an alternative to proprietary commercial online learning solutions, and is distributed free under open source licensing [10]. Silesian University of Technology has complete access to the source code and can make changes if needed. Moodle's modular design makes it easy to create new courses, adding content that will engage learners.

Moodle's intuitive interface makes it easy for instructors to create courses. Students require only basic browser skills to begin learning. Front page of typical e-learning course are presented on Figure 2.

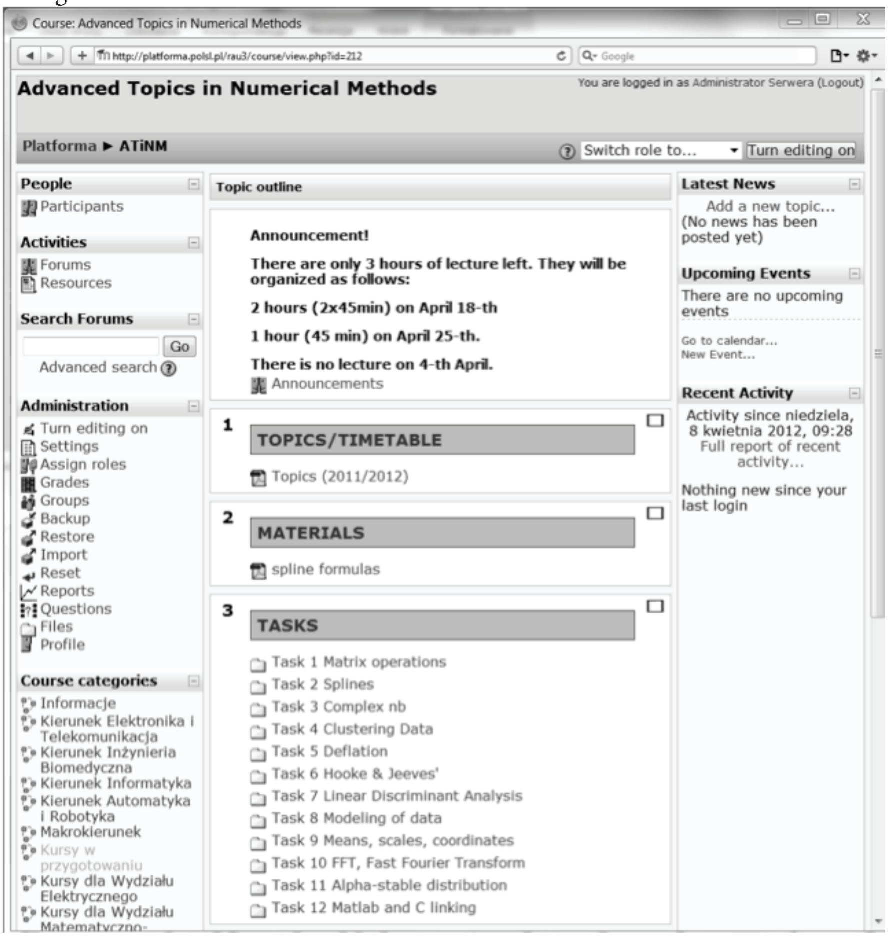

FIGURE 2. *Typical Interface of e-learning Course.*

The main advantages of Distance Learning Platform are:

- Promotes a social constructionist pedagogy (collaboration, activities, critical reflection, etc.),
- Suitable for 100% online classes as well as supplementing face-to-face learning ,
- Simple, lightweight, efficient, compatible, low-tech browser interface ,
- Easy to install on almost any platform that supports PHP. Requires only one database,
- Full database abstraction supports all major brands of database ,
- Course listing shows descriptions for every course on the server, including accessibility to guests,
- Courses can be categorized and searched - one Distance Learning Platform can support

thousands of courses ,
- Emphasis on strong security throughout. Forms are all checked, data validated, cookies encrypted etc.,
- Most text entry areas (resources, forum postings, journal entries etc.) can be edited using an embedded WYSIWYG HTML editor.

Working of Distance Learning Platform is based on four kinds of tools: site management tools, user management tools, course management and content management tools. All functions are implemented in separate modules.

4 DEVELOPMENT OF DISTANCE LEARNING PLATFORM - CONCLUSION

This paper presents Distance Learning Platform used by Silesian University of Technology. Platform is constantly developed. New interesting features are added as new modules to source code [12]. New Platform modules implements the most modern technology appears in web-based e-learning and Internet services. Example of them is: Web 2.0 technology [8].

Web 2.0, refers to a perceived second-generation of web-based communities and hosted services — such as social networking sites — that facilitate collaboration and sharing between users [7]. While interested parties continue to debate the definition of a Web 2.0 application, a Web 2.0 web-site may exhibit some basic characteristics [8]. These might include:

- “Network as platform” — delivering (and allowing users to use) applications entirely through a browser (web operating system).
- Users owning the data on the site and exercising control over that data.
- An architecture of participation and democracy that encourages users to add value to the application as they use it. This stands in sharp contrast to hierarchical access control in applications, in which systems categorize users into roles with varying levels of functionality.
- A rich, interactive, user-friendly interface based on Ajax (Asynchronous JavaScript and XML) or similar frameworks [9]
- Some social-networking aspects.

Majority elements of Web 2.0 technology listed above, are currently implemented to Distance Learning Platform [13]. Platform has great potential to create a successful e-learning experience by providing a plethora of excellent tools that can be used to enhance conventional classroom instruction, in hybrid courses, or any distance learning arrangements and significant contributes to increase efficiency of students’ education at Silesian University of Technology.

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225 INVENTIONS AS AN ENVIRONMENT FOR LEARNING

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ABSTRACT

Innovations can be used, in addition to pursuing economic benefits, as learning objectives and learning environments in many ways. In this paper, it will be described how innovations generated in Turku University of Applied Sciences (TUAS) are used as a support for learning. There are several patented inventions used for learning in TUAS: related to the patented Timperi frame system, an edge-glued laminated timber beam has been researched in cooperation with students since 2010; the OSD pile is a patented new way of making drilled micropiles; sealing sheet pile structures with cement is a patented invention for watertight underground walls and damping of soil vibration; the nutrition catcher is a patented method to reduce soil particles in flow-waters, e.g. ditches. In addition, the paper will cover description on a student competition in project learning contributing innovative proposals for new business and enterprises. Business development of inventions can be supported by new financing instruments introduced recently by Foundation for Finnish Inventions. The inventions have been a learning environment for Finnish students and, in addition, for many exchange students who have mapped the possibilities for use of respective inventions in Germany, Spain, France, Italy, Portugal and Brazil.

Keywords: invention, learning environment, innovation pedagogy.

1 INTRODUCTION

At Turku University of Applied Sciences, innovation pedagogy has a notable role in the institution's strategic policy. Innovation pedagogy aims at providing the students with professional skills that enable them to participate in innovation processes of their future organisations. It has been discovered – especially in Degree Programme of Civil Engineering – that the development of inventions and patents offers an interesting learning environment in itself. Although inventions and innovations are often developed for solving technical problems or challenges, a growing share of new innovations deals with the development of service processes, for example improvements in nursing care. The rights for technical innovations can be protected by applying for a patent; similarly, attempts can be made to protect innovations in service processes with a registered trademark or other similar methods. [1]

2 INVENTIONS IN THE CIVIL ENGINEERING STUDIES

2.1 Active learning and inventions

Active learning (Fig. 1) is one of the most important starting points for innovation pedagogy in TUAS. Teaching and learning are emphasized problem-solving, making and cooperation, which primarily focus on the student´s active involvement.

Various forms of invention based studies are available in the Degree Programme of Civil Engineering [2]:

a) Projects. Each student acquires a project assignment from working life to be completed in the guidance of a teacher from the degree programme. The compulsory project work strengthens the student's project skills and produces a natural channel for networking with working life. The topic of the project can be an invention.

b) Junior project hatcheries. All students in the Degree Programme of Civil Engineering start their studies in junior project hatcheries. The topic of the hatchery can be an invention.

c) Research hatcheries. A form of project-based learning that emphasises tutoring. A vast assignment from working life or a R&D project from TUAS is developed as teamwork.

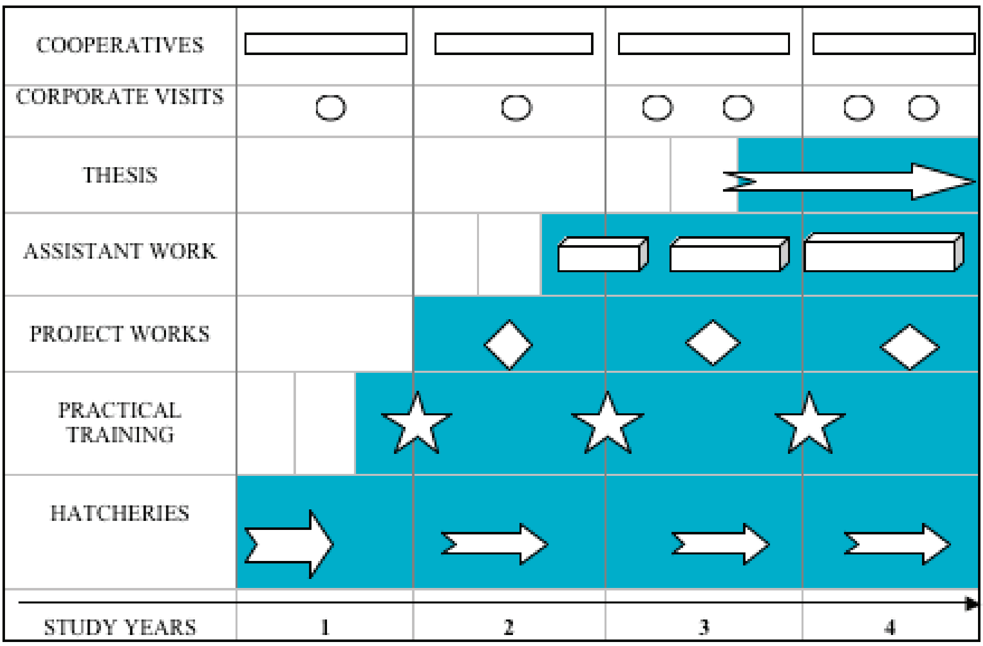

FIGURE 1. *Environments of active learning and working life connections in civil engineering studies; inventions are covered by the blue area.*

d) Expert hatchery. As a team, the students prepare the questions and record an interview with an expert, conducted either in a classroom or in the expert's own work facilities, for example a construction site. The expert hatchery method encourages experts, e.g. inventors, to join teaching and results in the students performing better in their studies as their topic gains attraction.

e) Planning and building detached houses. The degree programme has its own construction projects. The construction technology in protected with two patents.

Working with inventions (Fig. 1, blue area), research hatcheries and other forms of active learning are constantly developed further within the framework of innovation pedagogy. Several inventions, for which a patent or a utility model has been applied, have been made in the degree programme by teachers, project workers and students alike.

The students of the degree programme partake in R&D projects in various ways. They can participate as trainees, summer workers and student assistants as well as through thesis work, student cooperatives and research hatcheries. In addition to these possibilities, there are study units that are implemented as parts of ongoing R&D projects. Some parts of the studies related to R&D are compulsory (project hatchery, project work, practical training, thesis, certain study units), and some optional (research hatcheries, work in development projects).

2.2 Several patented inventions

The Timperi timber frame system [3] is a production technology of prefabricated houses created at Turku University of Applied Sciences. The development of the Timperi timber frame system has offered a whole range of study possibilities. Several theses and other works have been completed within the project. In addition, the students have participated in the design and construction of the houses as assistants. TUAS has purchased a site from the city of Turku for the construction of two detached houses, whose construction began in 2009. The degree programme will carry out the construction design, structural design and element design for both sites.

The OSD pile is a patented new way of making a so-called drilled pile. Unlike former steel piles, Open Section Drilling – that is, OSD – is utilised in an open profile and installed into the ground with a new kind of an eccentric drill. Developing the method sets challenges for the development of both pile material and pile driving equipment. [4] The OSD pile is developed in cooperation with Emeca Oy and Robit Rocktools Ltd. As a learning environment, the development of the OSD pile has produced half a dozen theses and several project works. When foreign exchange students have participated in research hatcheries at TUAS, they have been given a learning task related to the invention. A typical example of these learning tasks might be to find possibilities for the use of the invention in their home country. In the future, the development of the OSD pile could be continued in, for example, sales teaching or student cooperatives.

Sealing sheet pile walls with cement is a new patented invention made by a teacher and a student from the Degree Programme in Civil Engineering. By applying this method, it is possible to construct a completely watertight underground sheet pile wall [5]. Such a structure could be used, for example, when constructing an underground car park. The invention has been a learning environment for theses and several exchange students who have mapped the possibilities for its use in Central Europe, Portugal and Brazil.

Steel mesh can be utilised in road construction in various ways. With steel mesh reinforcements, the bearing capacity of soil can be improved, dents repaired and frost heave cracks prevented [6]. At TUAS, several Bachelor's theses in engineering and one Master's thesis in engineering have been completed on the subject. Steel mesh has been studied and developed for several years in close cooperation between Tammet Oy and TUAS. The company has developed the method from the point of view of technical production and applied for several patents in connection to the technology. The students of civil engineering have received the latest innovations as learning environments as soon as they have been made public.

The nutrient catcher [7] can be used to "catch" sediments and thus nutrients from water. Catchers will be suited for specific situations, such as water construction during times when water can contain high amounts of sediment and solute nutrients. Catchers will be suited for small streams and they are expected to assist in containing non-point nutrient loads from e.g. agriculture. Also the sediment loads from forest draining and peat production can be affected with the catcher.

2.3 Volume of studies among inventions

The timber construction inventions have been a learning environment for many years contributing credits for students (Table 1). In addition, the numbers of the table include study credits of the personnel. Two Master thesis and one doctoral dissertation have been finished in the Timperi development.

Main part of the credits is thesis based (Fig. 2), but the students have got credits on working in projects and exercises, too.

TABLE 1. Volume of studies in the Timperi development.

	2004	2005	2006	2007	2008	2009	2010	2011	2012	In total
Credits of exercise works*	-	-	30	30	30	30	30	30	30	210
Credits of project works*	10	10	10	10	10	10	10	10	10	90
Credits of thesis	45	15	-	-	75	15	-	30	240	420
In total	55	25	40	40	115	55	40	70	280	720

* numbers are based on teachers′ estimations

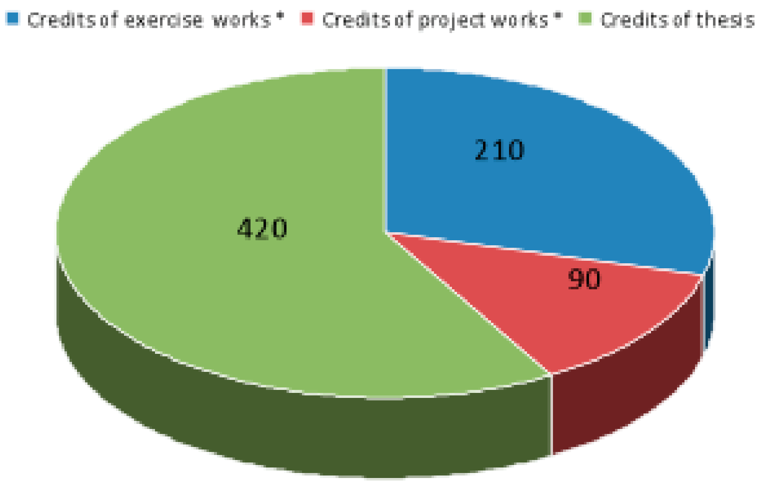

FIGURE 2. *The Timperi technology based study credits in Degree Programme of Civil Engineering. The thesis credits include number of credits from two Master Thesis and a Doctoral dissertation among the degree programme personnel.*

Exchange students have attended several R&D and innovation projects working and studying with topics as follows:

(i) micropile applications in Brazil, Portugal, France, Germany, Italy, Spain
(ii) sheet pile wall applications in Germany, France
(iii) wood structure applications (a German student).

3 POTENTIAL INVENTION ENVIRONMENTS

3.1 Case ICT Showroom

The ICT Showroom event [8] has been an example on students´ inventions as a learning environment. In the event, the students working in the ICT Building – a joint campus for University of Turku, Åbo Akademi University and Turku University of Applied Sciences – take part in a competition focused on innovative projects. The institutions participating in the event are the Information and Communication Technology departments of the universities locating in the same building. There are two kinds of contributions acceptable in the competition, student projects and research project presentations. A jury with industrial background evaluates the projects and selects a winning team.

Several projects in the ICT ShowRoom have contributed inventions and new applications generating potential to new business and entrepreneurship. Best inventions have been introduced internationally and some of them have been further financed by TULI financing (see Section 3.3.).

The ICT ShowRoom innovations have been clearly type of students´ initiatives giving a special potential to use inventions as a learning environment. However, the intention has been to create events with good spirit and relaxed atmosphere combined with competitions with considerable prices for the winner teams. [8]

3.2 iMill

Innovations can be evaluated and developed (Fig. 3) using the new iMill programme introduced recently by TUAS [9]. The iMill programme allows immediate support to the inventor in early phases of the innovation process. Any innovative idea can be brought through Internet to the iMill programme; the idea can be proposed by students or teachers of the university or by an inventor coming outside of the university. Creating and evaluating of ideas is an efficient method to learn innovation processes. If needed, IPR knowledge studies can be linked to the iMill working.

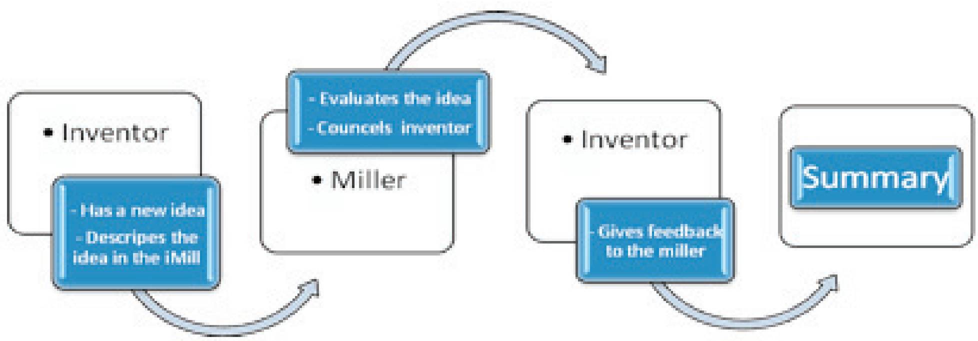

FIGURE 3. *Innovation process in the iMill.*

3.3 Further business development of the inventions

Tekes, the Finnish Funding Agency for Technology and Innovation, has financed the TULI programme for university based or student-inspired inventions and innovations [10]. TULI is an acronym for 'TUtkimuksesta LIiketoimintaan', which means 'From Research to Business' in English. TUAS has been involved with the TULI programme from 2008. During these couple of years the number of project ideas brought to the TULI programme has multiplied and the role of innovations has gained emphasis alongside with other R&D activities. At TUAS, about 50 projects have received TULI funding for commercialising services, research findings or inventions. Some of the projects have been initiated by the students, and several inventions have been patented and licensed.

TULI funding in universities of applied sciences has ended in the spring of 2012; later, similar funding can be applied for from the Foundation for Finnish Inventions (Fig. 4). TULI has offered an operating model for the development of innovation activities at higher education institutions as well as for supporting the commercialisation of innovations in such environments. For example, the confidential evaluation of ideas in consortium project groups has guaranteed the projects opinions of several experts and a neutral funding decision. Overall, the TULI programme has given birth to good results

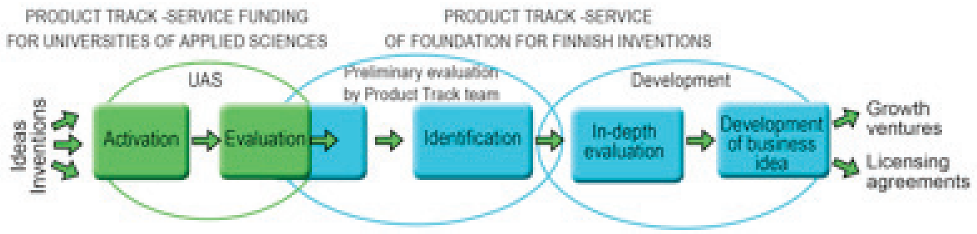

FIGURE 4. *Product Track –service Funding for universities of applied sciences is a new financing model to support business development of the inventions made by students or teachers. [11]*

at TUAS, the previously presented Timperi beam and the OSD pile being good examples of this.

4 CONCLUSION

Inventions and innovations offer an interesting possibility for innovation pedagogy and their production is one of its central objectives. In the production of innovations (Fig. 5) two closely related concepts are connected: learning and developing. They often appear as two aspects of the same concept. The student can learn several issues in the innovation process, covering e.g. tacit knowledge, networking, shared expertise and challenges to meet uncertainty.

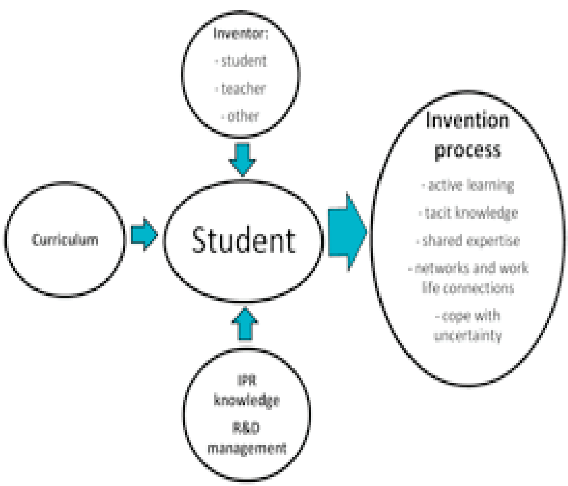

FIGURE 5. *Invention based studies are typically linked to the invention and the inventor, IPR knowledge and R&D management allowing student to participate invention process.*

At its best, innovation is an inspiring and challenging learning environment for the learner – developing is like being at the frontiers of existing knowledge and abilities, reaching out for the unknown. When developing innovations, the students recognise the information that is supposed to be found through studying. Innovations also include the risk of failure which is an integral part of development in the context of working life. Facing risks and failures is valuable capital which a student can acquire when working with innovations.

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226 STUDY COURSE COOPERATION MODEL FOR ENTERPRISES AND SAMK – CASE OFFSHORE

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ABSTRACT

Two years ago, SAMK (Satakunta University of Applied Sciences) launched a 5 credit course simply named ”Offshore”. The objective is was, and still is, to provide students with a broad overview and understanding of the process of oil production, starting from geological surveys of potential offshore oil fields, developing an oil field and ending with refined oil. The coastal region in Western Finland has traditionally been strong in producing rigs and equipment for offshore oil production and related disciplines.

Need for qualified young professionals is clear and, to answer the industries' call for educated engineers, SAMK is constantly adjusting the contents of provided education. Correct adjusting would not be possible without constant and open communication between all parties involved. One of several examples of effective co-operation is how this "Offshore" course was developed and organized.

The course topics include geological surveying, exploration drilling, planning and developing of offshore oil fields and production platforms, processing of gas and oil, distribution as well as HSE issues, to name a few. All lectures are held by visiting lecturers, from leading Finnish offshore companies, who are experts in their discipline. The course has proved to be very successful among students and even if the amount of free spots on the course would be doubled, not all applicants could be accepted.

Keywords: Offshore, SAMK, Oil Production, SPAR,

1 INTRODUCTION

Companies like Technip Offshore Finland Ltd, Wellquip Ltd, Kvaerner Finland Ltd among others are located in the proximity of SAMK's Pori unit. Some contributing factors in the success of these companies have been strong engineering skills and the availability of young skilled engineers. This is where SAMK has played an important role.

The idea of launching such a course was a result of brainstorming between SAMK, Western Finland offshore companies and OTC (Offshore Technology Center), an organization giving a wide range of training in the field of offshore oil production.

The course has proved to be very successful among students and even if the amount of free study places in the course would be doubled, not all applicants could be accepted. Although the course is very demanding and the students get new assignments every week during the spring term, they show great interest towards the Offshore course. The assigned essays are all returned and evaluated.

This spring 2012 was the third time the Offshore course was organized. Most probably SAMK will arrange the course in future springs, too. This course demonstrates how mutual interests and co-operation between a higher education institution (SAMK) and the industry can result in an outstanding course, which fulfills the needs of both students and the industry.

Today approximately 20-25% of SAMK's Bachelor's theses in the Mechanical Engineering programme are done for closely offshore related industries. Combining this course with other SAMK courses, e.g. production engineering and machine design, will ensure sufficient skills for young engineers. SAMK will carry on developing education to meet the requirements of dynamic engineering fields.

1.1 Student selection

This course has been very popular since the first time it was organized and students are still enthusiastic to participate. Clearly, previously attended students have spread the word of an interesting and non-traditional as well as useful course.

The number of students in the course has been limited to approximately 30 students, because safety issues during factory tours have to be guaranteed, and to keep lecturers´ workload on a reasonable level. In 2012 we had more than 60 enrolled students, which was approximately at the same level as during previous years, and therefore participation had to be limited.

Selection was made by prioritizing senior students from suitable educational programmes. 4th and 3rd year students had privilege over younger students as well as Mechanical and Industrial Engineering students over other degree programmes. Also previous study success was a factor in student selection.

There are several justifications for using these factors. 1st and 2nd year students will most probably be still studying when the course is held again, so they will have the possibility to participate at a later stage. Also the content of the course is not novice level and some degree of expertise and in depth knowledge is highly recommended to get the most of it. This is also the main reason to prioritizing certain degree programmes over others.

FIGURE 1. *Photograph of students during a factory tour*

1.2 Assignments

During the introductory lectures the students were grouped into teams of 2-3 students for coming assignments. These groups received 8 mandatory written assignments in total with topics based on each lecture. The assignments were prepared and graded by the visiting lecturers.

Having a lecturer from the industry preparing and grading the assignments is very beneficial to the students as they receive "real-life" opinions on their work instead of text-book based comments.

At the end of the course the last lecture is designated for the student groups presenting their assignments to other course participants. As there are approximately 15 groups the presentation is limited to 10 minutes per group.

Some examples of the assignment topics are: "Introduction of major oil companies", "Exploration drilling", "HSE", "Selection of an oil production platform" and "Design factors of an oil development field".

1.3 Lectures

SAMK´s main partner in organizing this series of lectures is OTC (Offshore Technology Center). The opening and closing lectures were held by OTC.

Other lectures were held by professionals in their field from companies located in Western Finland.

Using representatives from potential future employers instead of staff lecturers motivates students a lot. These lectures by industrial experts give a real life perspective to the course, and also shows industry's commitment and interest toward students .

TABLE 1. shows the companies and lecturers involved in giving the and also lists the topics.

Lecture schedule - Offshore		
	Lecture topic	Lecturer
1	Offshore production of oil and gas	Kimmo Juurmaa, Deltamarin Oy
2	Global energy economics, oil and gas	Kaija Tikka, Offshore Technology Center Oy
3	Exploration and research: geological prospecting and geophysical research	Heikki Hämäläinen, Geopros Oy
4	Exploration and research: exploration drilling	Heikki Välitalo, Aker Solutions AS
5	HSE	Jarmo Kivi, Technip Offshore Finland Oy
6	Offshore production; structures, processes and operation	Kimmo Savo, Technip Offshore Finland Oy
7	Establishing an offshore oil field	Kimmo Savo, Technip Offshore Finland Oy
8	Development of and offshore oil field and project management	Juha-Pekka Pykilä, Kvaerner Finland Oy Hanna Matomäki, Kvaerner Finland Oy
9	Final session: Student assignment presentations	Kaija Tikka, Offshore Technology Center Oy

1.4 Company visits

One essential and mandatory part of the course is visits to offshore companies in the region.

During the latest course the following companies were visited: STX Finland Rauma shipyard, Rolls-Royce, Pemamek, Wärtsilä, Technip Offshore Finland, Kvaerner Finland and Hollming Works.

These professional study visits were an excellent possibility to deepen the understanding of what was learned in theory during lectures.

Despite the fact that almost all students had learned of TOF and SPAR-hulls and knew the size of such a structure, only few had actually seen one. Technip Offshore Finland (TOF), one of the companies visited, has one SPAR-hull under production at the moment and it was very eyes-opening to realise the magnitude and complexity of constructing such a steel structure. Once again it became evident how important it is to have professional site visits along with classroom sessions.

2 OFFSHORE STUDY COURSE FEEDBACK

Those students who participated in the Offshore studies evaluated the study course. The feedback system is similar to all study courses organized at SAMK. In fact, to receive the grade and the ECTS points students must give their feedback through the electronic feedback system. This evaluation process is based on the quality assurance system applied at SAMK, and the procedural guidelines define the course feedback procedures. In the feedback students give their opinion on three questions: 1) Evaluate your own learning outcomes and the accuracy of the work input dimensions indicated in the course description, 2) Make suggestions as to how the course could be further developed, 3) Evaluate how well the set objectives indicated in the course description were attained. The final fourth question is to give a numerical evaluation of the course as a whole. Students will use the scale from 1 to 5, where 1 equals to a very bad, and 5 equals to a very good course.

The following analysis is based on the Offshore study course feedback from spring 2011. At the time of the official feedback session, which took place in September 2011, 27 students out of 34 enrolled students had given their feedback. Thus, the feedback percentage was 79. The mean numerical grade was really good 4,19.

As to the learning outcomes, the course was successfully organized and the content covered widely the offshore industry and its future trends. The close relation to the offshore companies, and the lecture integration to the sites gained positive feedback. The lectures given by visiting lecturers from the offshore industry were interesting and practically oriented. Students said that they learned a lot from the team based exercises. As far as the workload was concerned, the course was ranked to be quite demanding. However, students did not complain about the amount of work, because the study methods in the course included a variety of interesting methods, and students gained current information on the offshore issues.

Most of the feedbacks indicated that the course need not be further developed. So, the main organization of the study course fulfilled the students' expectations. The only development ideas were related to the utilization of the virtual learning environment Moodle, to the arrangements of the site visits, and to the information about training and employment possibilities in the offshore companies. The content covered a wide range of offshore topics, and there were only a few comments on the subjects. The offshore windmill applications could be included in the study programme. Students gave only some comments on the set objectives. Almost all feedback indicated that the set objectives were fully achieved.

3 CONCLUSION

The final feedback of this year's, 2012, course is not yet available, although based on opinions heard during the course, it was a success and highly appreciated by students.

Organizing this kind of education is not an easy task as there are several parties involved and high commitment is needed both by the visiting lecturers and students . This Offshore course has proved to be very successful as well as very intensive, time consuming and has no doubt meant a lot of work to the students.

Despite the high workload there is mutual interest between SAMK and enterprises to arrange this kind of education as it is a very effective way to educate young professionals in an important but topically focused segment in engineering. This is also a great possibility to familiarise the students with a variety of engineering and offshore and oil related companies.

4 ACKNOWLEDGEMENTS

This course is a group effort and could not have been accomplished without the assistance and involvement of companies and individuals giving lectures and arranging factory tours.

Special thanks to all individuals mentioned in this paper for their contribution.

227 MECHANICAL ENGINEERING PRACTICE EDUCATIONAL CENTER OPERATING BY BOTH UNIVERSITY AND INDUSTRY

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ABSTRACT

To meet the need of industry for qualified engineers, China ministry of education launched the excellent engineer education training program in 2010, which encourage universities and enterprises to have a full cooperation on the engineering education. HuaZhong University is one of the first batches of 22 universities to involve in the program. For School of mechanical engineering of HuaZhong University, we invited some large-scale enterprises, such as Sany Heavy Industry Co Ltd, to take part in the excellent engineer education training program, and three mechanical engineering practice educational centers have been built in participating enterprises. Before the graduation, senior students will service in these centers and enterprises for one or two month. In this enterprise service period, they will learn much useful practical knowledge of engineering that are not included in university's curriculum. These centers have been running for two years, and five groups of students have finished their enterprise service, which show a great success. The paper introduces the operating procedure of these mechanical engineering practice educational centers.

Keywords: Mechanical Engineering, Engineering Education, Practice Center

1 INTRODUCTION

To meet the need of industry for qualified engineers, China ministry of education launched the excellent engineer education training program in 2010, which encourage universities and enterprises to have a full cooperation on the engineering education. This takes an important role in China's engineering education reform.

The Program has three characteristics. First, it sets a general standard for excellent engineer education. Second, it emphasizes on the cultivation of students' engineering capability and creative ability. Third, it encourages and funds to build the engineering practice educational centres that are operated by both university and industry. [1]

HuaZhong University of Science and Technology is one of the first batches of 22 universities who are involved in the program, and the mechanical engineering is selected as a pilot. To fulfil the program, we started related work even before 2010. An excellent engineer training standard and curriculum for mechanical engineer is designed out. And three mechanical engineering practice educational centre has been built with industry. These centres have been running for about two years, and a large amount of student has been sent there for engineering practice education. From the feedback information of industry people and students, the program gets a success.

2 EXCELLENT ENGINEER TRAINING STANDARD AND CCURRICULUM

To control the quality of engineer education, China ministry of education set a general standard for universities involved in the program, and requires an at least one year's training time in industry. Ten aspects are included in the general standard of China ministry of education.

(a) Students should have a good education in social science, and have a good understanding of professional and ethical responsibility.
(b) Students should have an understanding of modern industry, and students need to think about problems of quality, service, environment, occupational health and safety.
(c) Students should have a good education in science, and have knowledge of mathematics, economics and management.
(d) Students should have a good education in engineering, and have knowledge of factory, manufacture, equipment and products.
(e) Students should have knowledge of technical standards, policies and laws.
(f) Students should have abilities to acquire new knowledge and to engage in a life long learning.
(g) Students should have an ability to use their knowledge to solve engineering problems.
(h) Students should have an ability to innovate new techniques and new products.
(i) Students should have an ability to work in a multi disciplinary team and to communicate effectively.
(j) Students should have an ability to cope with crises and emergencies.

To fit need of the general standard, we design a ccurriculum of "3+1(1+3)". The ccurriculum means students should take three years studying theories in university and should take about one year to learning engineering ability in industry. The one year's practice time is separate into four parts again. The social practice is two weeks long and is arranged in the summer of first year. In this period, each group of students selects a social problem that they interested, and then survey how the problem is formed. The engineering practice I is two weeks long and is arranged in the summer of second year. In this period, students visit different types of enterprise together, and get a real feeling what an enterprise look like. The engineering practice II is eight weeks long and is arranged in the summer of third year. Students are juniors now; they have learned many theories and have some engineering knowledge. In this period, each student need to work in one or two positions in a enterprise for a short time, and get a real experience of what a engineer's work is. The engineering practice III is sixteen weeks long and is arranged in the last semester of fourth year. Students are seniors now; they have finished all their classes. In this period, they are sent to enterprises to do their thesis. They need to use what they have learned to solve an engineering problem. Just like a real engineer will do.

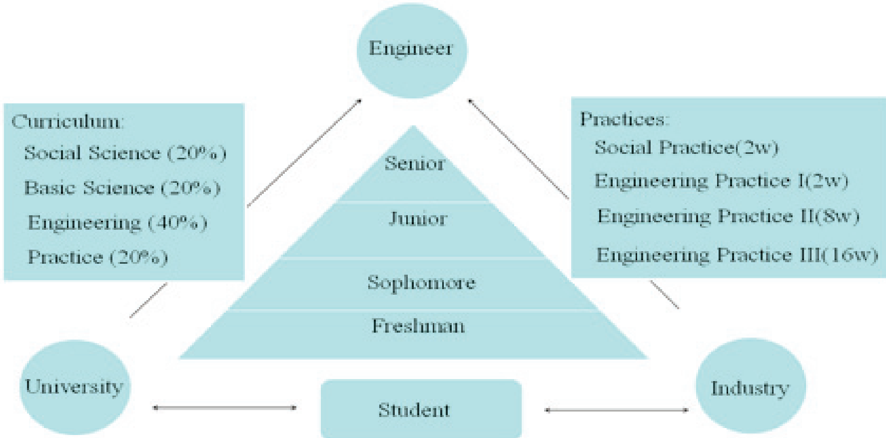


FIGURE 1. *The ccurriculum of "3+1(1+3)".*

3 ENGINEERING PRACTICE EDUCATIONAL CENTER

In the new ccurriculum, there is nearly one year of practice time in enterprises. Therefore, some kind of engineering training agencies must be established by both universities and enterprises, and all training activities of students should be arranged by these organizations. Generally speaking, the engineering practice educational center will take five duties.

(a) It needs to negtiate with the enterprise to arrange the internship and to supply training places and positions for students.
(b) It needs to work with both the university and the enterprise to define the engineering training plan and the engineering training standard.
(c) It needs to evaluate the training quality of students when the enterprise practice stage is finished.
(d) It needs to have a faculty team that is come from both universities and enterprises.
(e) It need to have a powerful management system to push things going.

The engineering practice educational centre is a bridge between universities and enterprises. Figure 2 is the architecture of the engineering practice educational centre that is built by our university and three enterprises.

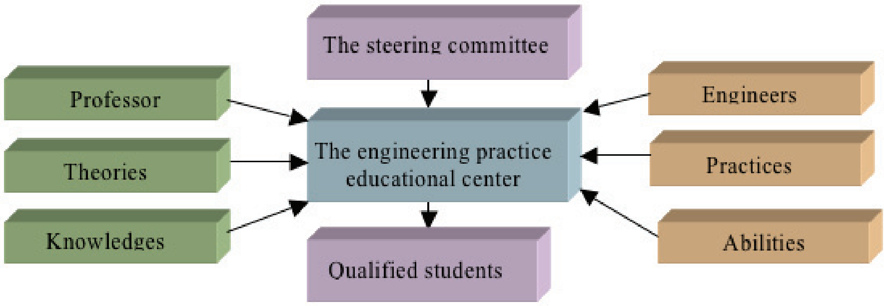


FIGURE 2. *The architecture of the engineering practice educational center.*

4 APPLICATIONS

4.1 Social Practice

The social practice is arranged in the summer of first year. Students are separated into group of about ten people. They take two weeks to survey a social problem. Through this activity, students will have a chance to enhance their understanding of the society, and to increase their social responsibility. Figure. 3 show that a group of students was visiting a school for children of poor migrant workers. Before going to the school, students organized activities in the campus calling people to donate their unused books to that school.

FIGURE 3. *The survey of the education condition for children of poor migrant workers.*

4.2 Engineering Practice I

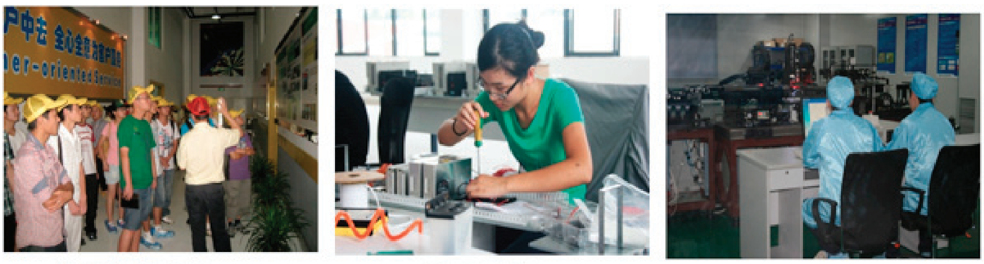
The engineering practice I is arranged in the summer of second year. For a two weeks long time, students are separated into a small group of ten people, and each group will go to three or four enterprises. The engineering educational centre there will arrange a guided tour for students, and show them how a product is manufactured out. Figure. 4 are three typical enterprises that students will visit, Wuhan Iron and Steel Plant, Wuhan Dongfeng Motor Corporation and Wuhan Heavy Machine Tool Plant.

Wuhan Iron and Steel Co., LTD   Dongfeng Motor Co., Ltd.   Wuhan heavy machine tools Co., LTD

FIGURE 4. *Three typical enterprises.*

4.3 Engineering Practice II

The engineering practice II is arranged in the summer of third year. For an eight weeks long time, students will go into an enterprise and work in positions like design, manufacture and marketing. By this way, students can experience what an engineer's work will be. Figure 5 shows that students were doing their practice work in Dongguan Hustinova Precision Machinery Co. Ltd.



Safety Education   Do research   As Worker

FIGURE 5. *Working in Dongguan Hustinova Precision Machinery Co. Ltd.*

4.3 Engineering Practice III

The engineering practice III is arranged in the last semester of fourth year. For a sixteen weeks long time, students are separated into a group of three or four people, and each group will take a project that is come from an enterprise. Students will try to think like engineers, and find a solution for the enterprise. Figure 6 is an experiment device that is designed by a group of students, which has been used to test the life of an abrasive belt.

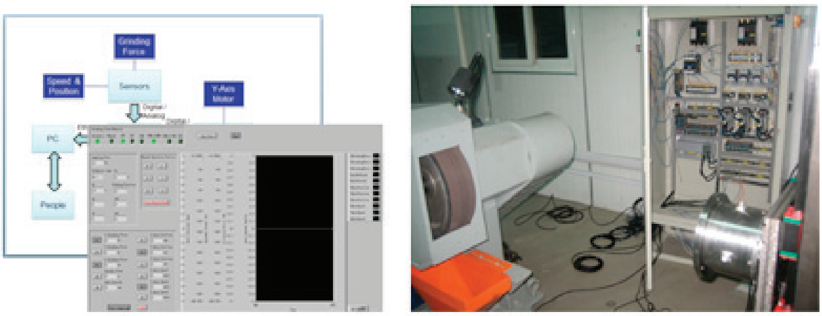


FIGURE 6. *The experiment device that is designed by students.*

5 CONCLUSION

The new ccurriculum has been used for two years and two batches of students have finished their practice. Students, university and enterprise are satisfied with this reform. It has a win-win-win result. The excellent engineer education training program is a direcator, it point out the direction of the engineering education reform.

6 ACKNOWLEDGEMENTS

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229 ABOUT A SYSTEMATIZATION OF THE DESIGN PROCESS OF ORIGINAL EQUIPMENT

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ABSTRACT

This article describes an innovative proposal of a methodology design oriented at developing original equipment which can be used for engineering education. The methodology consists of 9 phases: 1) analysis of customer requirements, 2) conceptual design, 3) body design, 4) design detail 5) manufacturing and assembly, 6) testing and validation, 7) industrial transference, 8) life cycle analysis, and 9) industrial upgrading and technological innovation. These stages help students to contextualize and locate the different subjects carry during his career and also serve the industry to systematize the programs and procedures with which are designed and manufactured equipment and machinery. The methodology includes steps ranging from quotation and the contract of a project through to delivery and startup of equipment designed. Each phase is described as a program or procedure of the design process and for each phase are given a series of steps to follow in the design of a product. Finally, the methodology presented in this article has applications in teaching and in industrial development of original equipment and machinery.

Keywords: Equipment design, Engineering education, projects.

1 INTRODUCTION

One of some problems that have to face the engineering education is the contextualization of knowledge, meaning, ensure that the students find meaning to the knowledge they learn in college, particularly in industrial development. The student participation in projects with predominantly academic difficult the contextualization because ignore the needs of industry and lacking the experience necessary for the development of productive projects, such as original equipment design. Certainly the need to train students with pedagogical models such as the application of Kolb's model described in [1], so development of skills in machine design must be motivated from laboratories to the development of experimental prototypes. However, not to reinforce the training of industrial projects involving students who graduate with deficiencies in aspects such as unknown of knowledge about project contributions, lack of analysis of customer requirements, little experience to take decisions in machine designs, unknown of providers and contracts of employment, lack of knowledge to use policies and validation design, little knowledge of industrial transfer and machinery cycle life, and lack of knowledge on patents and industrial property and little knowledge on methods of reverse engineering, among others.

To achieve the industrial contextualization of original equipment design in engineering students, are required to participate in industrial projects and used in a systematically ways procedures related to the phases of design and reverse engineering [2], as usually projects design of original equipment require the use of knowledge gained by the application of reverse engineering procedures. To be most effective in engineering education, programs and phases of the design methodology should be improved through the experience of designers. In this paper is presented the explanation of the methodology steps for the applied design to the development of original machinery, which was reinforced by the experience of designers. This methodology is the result of projects development to industries, mainly to SMEs.

2 DESIGN PROCESS

The original equipment design refers to the development of technologies which are usually part of an idea derived from customer requirements, and the goal to a product that may well be new (original) or may be developed as partial or total (without the designer has full access to information). The product obtained must be transferred to the client. The development of original equipments requires interaction between project management and process design, analysis of the product life cycle. The domain of the workflow during the design process for the students is essential for the development of projects and their educational background. In [3] describes the following steps related to the workflow design process: 1) clarification of the task, 2) conceptual design, 3) body design and 4) detail design. On the other hand, in [4] proposes the following stages or phases which are related to the product life cycle: 1) development specification / planning, 2) conceptual design, 3) product design, 4) production, 5) service and 6) product recall. In [5] proposes 9 phases for the process design, including in part, stages of project management and product life cycle. These phases are: 1) customer requirements analysis, 2) conceptual design, 3) body design, 4) detail design 5) manufacturing and assembly, 6) testing and validation, 7) industrial transference, 8) product life cycle analysis, and 9) industrial improvement and technological innovation.

3 METHODOLOGY DESCRIPTION

At first instance, original products development requires an initial client contact, which describes a range of needs and requirements. The first goal of the designer is to transform customer needs, using their experience and analysis to a quote in a short time. The analysis phase of customer requirements is essential, from it depends at great scale the development project [5]. Once approved the quote, the second phase is to develop in a systematic manner or main ideas that results in a quote. This phase is called the conceptual design and is perhaps the part that requires creativity, because technically is the phase in which the set up have a high percentage of the final design. Experience and knowledge development are the keys to obtain a conceptual product design. The third phase is called the body design and the fundamental purpose is to validate technically and scientifically the product of conceptual design. The design phase of the body is responsible for applying principles, laws, theories and knowledge based on experience, and engineering variables to calculate the proposal for validate the product made in the conceptual design. The detail design phase aims to refine and transform information from spreadsheets to manufacturing information. This phase has two main purposes: 1) detail the basic elements that the conceptual design and body design did not contemplate and 2) to transform information design for manufacturing information, means, manufacturing drawings. In the phase of components manufacturing and assembly are generated according to the information described in the manufacturing drawings. Subsequently, the physical prototype with all the available arming elements system. In phase related to testing and validation is performed all necessary tests to the prototype in order to validate and transform the prototype machine. Generally, the design, to be technically defined by the theories, considers some important parameters like others do not. Testing of the prototype phase is to evaluate whether those variables that were not taken into account may pose risks.

In the industrial transfer phase, the finished machine or system is ready to be transferred to the company. In the analysis phase of the life cycle is monitored the machine operation transferred to the customer following two purposes: 1) to have information about the operation field and machine problems, and 2) to have information about how operators work with machines, in order to conform to the guarantee scheme. Finally, the phase of industrial improvement and technological innovation focuses on the development of improved products. Transferred industrial machines comply with specific functions. Improvements and industrial needs require the generation of new machines or systems that may well be built on the basis of the products that work in companies.

4 PRODUCTS SYSTEMATIZATION DESIGN

This section presents the activities associated with the methodology phases proposed in [5]. It exposes each phase in terms of the following steps.

4.1 Customer requirements analysis

1) The client makes a request or need for the designer.
2) Is made an appointment with the customer.
3) The customer explains his need.
4) The developer analyzes the information in conjunction with the client.
5) A first sizing of necessity is done, that is, put the first technical limits.
6) Will reach a first agreement on the machine design.
7) The developer performs a process of technical and economic analysis more precise to customer needs.
8) A preliminary quote is generated.
9) Is quoted to the customer and described the quote.
10) Is reached a second agreement that usually involves an employment contract.

4.2 Conceptual design

1) Study of a depth quotation and the contract.
2) Systematize the idea or set of technical ideas that gave rise to the quote.
3) Propose the first operational principles.
4) Perform a search for similar designs or equivalent of required equipment.
5) Propose ideas discussed about solving the problem.
6) Use graphics computing resources to turn ideas and proposals in virtual goods.
7) Analyze the proposals and decide which formal idea will be guided the product design.
8) After selecting the guiding idea proceeds to detail it, systematizing the idea into subsystems.
9) Each subsystem is analyzed separately, taking the customer requirements and costs.
10) In general, each subsystem has an associated operational principle.
11) Each subsystem is designed looking at least functionality.
12) Are related in a first phase of each subsystem, i.e. Particular relationships are determined among the first operating principles.
13) The overall system is armed, that is, the system governing the machine proposed design.
14) Are discussed the final proposal design.
15) Adjustments are made to the proposed conceptual design.
16) Are reported the proposed design.
17) New appointment with customer to validate the conceptual design.
18) Product is obtained, in this case is the idea processed into technical documents such as drafts, three-dimensional drawings, technical information materials, components, parts and components, information of each proposed systems that make up the machine or system, memories of the technical discussion on all the client's approval.

4.3 Body design

1) Analyze the conceptual design technical proposal.
2) Decompose the systems proposed.
3) Determine the theoretical needs of each system.
4) Identify the methods and techniques required to analyze each system.
5) Determine the empirical knowledge that is required for each system.
6) Define the problem in each system to be solved.
7) Identify the computational tools, mathematical and experimental required to solve the problems.
8) Apply knowledge, theories and methods developed to solve each problem.
9) Find the solution to every problem raised.
10) Simulate the solutions, if necessary.
11) Create a worksheet for each analyzed system.
12) Aggregating the calculations of the entire system.
13) Validate the conceptual design.
14) Make adjustments to the proposed design.
15) Generate the information of the body design model.

4.4 Detail design

1) Gather information from previous phases.
2) Analyze the systems that make up the product and evaluate the missing elements or parts.
3) Analyze and detail each missing part.
4) Get the worksheet of each detailed part.
5) Aggregating the main parts of the design with the secondary parts.
6) Validate the complete systems.
7) Make the necessary adjustments.
8) Build a database of all information generated so far.
9) Separate roughly manufacturing information and geometric information of each part.
10) Select the appropriate standards to represent the geometric information and manufacturing.
11) Select an auxiliary computational software to the manufacturing drawings generation.
12) Generate the manufacturing drawings of each item designed.
13) Get the information of each piece that was acquired without the needed of design it.
14) Review all technical information.
15) Generate a report which has the drawings information results, of each piece information, of manufacturing information and notes with important details.

4.5 Fabrication and assembly

1) Detailed analyze of the information from the design.
2) Develop a manufacturing plan.
3) Search providers, manufacturing and purchasing of parts and components, or prepare the machines if necessary to have their own workshop.
4) Send the manufacturing drawings to suppliers or to the workshop itself.
5) Acquire the parts which do not require production.
6) Supervise the work of manufacturing suppliers or workshop.
7) Receive and store all parts and devices.
8) Validate products suppliers.
9) Design an armed and assembly program taking all available information in previous phases.
10) Assemble the system according to the program designed.
11) Provide final adjustments of the system.
12) Get the prototype.

4.6. Testing and validation

1) Analyze all the information of the previous phases and the prototype.
2) Disassemble the prototype as necessary to subsystems.
3) Gather customer requirements.
4) Find appropriate standards for testing.
5) Develop a test plan, for example, test subsystems and the overall system
6) Apply the test plan to the systems.

7) Compile and analyze test data.
8) Evaluate the results.
9) Reset the design if necessary.
10) Validate or invalidate the prototype.
11) Generate a report of results.

4.7 Industrial transference

1) Prepare a technical report of the parties and the main functions of the machine to be transferred.
2) Plan is designed for industrial facility.
3) It is designed a test plan on the facility.
4) Is generate a maintenance report.
5) Is generated a training course of the machine.
6) Prepare a report of patent rights or utility models in case of be required.
7) Develops delivery document that includes the guarantee scheme of the machine and the completion of the project.
8) Is installed the machine or system in the industry.
9) It set up the machine.
10) Are made the necessary evidence.
11) Necessary adjustment and calibration are made.
12) Personnel are trained.
13) Officially given back to the client's project.
14) The contract ends.

4.8 Life cycle analysis

1) Gather information about the life cycle of each piece that makes up the machine or device.
2) Generate a series of visits to the company to observe the operation of the product transferred.
3) Make a survey of the information provided by operators about machine problems.
4) Check if the operators are correctly implementing the operation and maintenance manuals.
5) With the provided information should analyze the problems with the machine.
6) Propose practical solutions to every problem.
7) If necessary, reset the running machine.
8) Generate a report with all information.

It is noteworthy that the monitoring must be transferred and installed to the machine until its life cycle ends. The information that sheds the monitoring is essential to: 1) have control on safeguards, 2) give better customer service and information for continuous improvement of the machine.

4.9 Industrial improvement and technological innovation

1) Gather all the machine technical information, in design and transference, as the information obtained from the life cycle.
2) Meet the future needs of customers.
3) Know the context of scientific and technological advances.
4) Analyze the transferred machine and implement procedures for reverse engineering.
5) Propose improvements to the systems of the machine or device.
6) Redesign the machine according to the new specifications and information life cycle.
7) Build and validate new prototypes.
8) Transfer the new products to industry.
9) Promote continuous improvement projects in companies.

5 CONCLUSION

In order for engineering students to contextualize the knowledge learning in the classroom, they need to participate in projects that involving; first, industrial requirements, and on the other hand, the use of design methods that allow them to know all the phases that occur in the original equipment design. The methodology proposed in this paper, integrating experiences of designers provides to the students knowledge of great value, allowing for interactions between client and developer, and especially be aware of the enormous importance of the conceptual design phase, development of body design and detail design projects. In addition, the phases of validation and industrial transference are essential for students to know the differences between prototype and machine, and the different requirements needed for installation of machinery. The phases of life cycle analysis of the product and technological innovation, allow students to know that the design of a machine does not end with the transference to the company, but it is necessary to monitor for future corrections and that improved technology is essential.

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230 STRUCTURED LEARNING JOURNAL BASED METHOD FOR LECTURE COURSES IN ENGINEERING EDUCATION

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ABSTRACT

We present our learning journal based teaching method which directly addresses the problem of uneven study effort division during the course. Students return their learning journal entry each week, and at the end of the course they combine the weekly entries and finalize the entirety into the final learning journal. When students are required to write an entry to their learning journal each week on given topics throughout the course, they have to process each week's course topics more deeply than they would in case of an examination. This way, the learning process is spread evenly across the entire duration of the course, resulting in better achieving of intended learning outcomes and deeper learning of the key topics. At the same time, the weekly entries can be used for receiving instant feedback from students of each week's lectures, exercises and reading materials. The results and experiences of the case study make it evident that our original assumptions were correct: intended learning outcomes are reached better, students obtain a deeper understanding of the key course topics and the weekly entries provide an excellent channel for instant feedback from students.

Keywords: Learning journal, Lecture course, Curriculum planning.

1 INTRODUCTION

We have observed that engineering students in our information technology curriculums are able to allocate less and less time each year for deep thought on the subject matters covered in their courses. The trend is more and more towards spending as little time as possible for coursework, just enough to fulfil course requirements. One possible reason for this could be the good chances our students have in the Turku area of being recruited by companies in the information technology sector already in the early stages of studies. The reduced time spent on coursework has a direct effect on the level at which learning outcomes are achieved, especially in courses organized as lecture courses with an examination held at the end of the course. The study effort emphasis seems to be shifting more and more towards the few days before the examination from the more ideal evenly spread effort across the duration of the course.

In this paper we present our learning journal based teaching method which directly addresses the problem of uneven study effort division throughout the course. Students return their learning journal entry each week, and at the end of the course they combine the weekly entries and finalize the entirety into the final learning journal. The learning journal is graded, and there is no examination at the end of the course. When the students write an entry of their learning journal each week on given topics throughout the course, they will process each week's course topics more deeply than they would in the case of an examination. This way, the learning process is spread evenly across the entire duration of the course, resulting in better achieving of the intended learning outcomes and deeper learning of the key topics. At the same time, the weekly entries can be used for receiving instant feedback from students from each week's lectures, exercises and reading materials.

We present a case study of applying the learning journal method in a Bachelor's level engineering course. The method is tuned to fit the exact needs of the course in question and the attending student pool.

The rest of the paper is organized as follows. In section 2 we proceed to a discussion on the worthiness of learning journals as tools in ensuring the learning outcomes on courses, and on monitoring the learning curve of the participants throughout the course. We also present our methodology for applying structured reflective learning journals to practice in engineering education. Then, in section 3 we present the case study of applying the methodology on a course. Finally, in section 4 we draw our conclusions.

2 REFLECTIVE LEARNING JOURNALS FOR ENSURED LEARNING

A reflective learning journal is essentially a critical reflection of the things the student learns during the lectures. Learning journals have been used for quite some time. One of the pioneers of learning journals was Paul Hettich, who used the learning journals in 1970's with psychology students [1]. The original learning journals were aimed at learning by a writing process which was at those times very popular in the USA.

In the writing process the student connects the learned topic to earlier knowledge and experience. This improves the student's ability to understand large entities. Reflective thinking is directly connected to larger metacognition, or simply thinking about thinking or knowing about knowing. With the help of metacognitive skills the student can analyze his own learning, actions, thinking and skills [1]. Understanding one's own logical errors and faults is essential for an effective learning process.

A student forms actively his own conception of the topic while writing a learning journal. This is important for learning and understanding the issues on a deep level. The writing process forces the student to analyze the lecture notes deeper than in plain reading.

A proper learning journal requires good instructions to the students. Questions may be given to the students, for example: "What did I learn", "What would I like to ask" and "What am I thinking" [1]. All instructions have to be carefully considered as they tend to bias students reflection process.

Learning journals are at their best in groups with less than 20 students. In small groups the learning journal will help forming a personal connection between the teacher and the student. Ideally a learning journal activates communication between the students and the teacher. It is quite common to find a student continuing an interesting lecture discussion in the learning journal.

Large classes are somewhat problematic and need special arrangements for learning journals. As the personal connection between the students and the teacher is no more possible, analyzing and grading of the students works becomes almost impossible. The effectiveness of the learning journals decreases. One way to reduce the teachers work load is to let the student select his best learning journal entries for grading. Another solution is to split the class in small groups for peer review.

The grading of the learning journals is sometimes difficult. Grading has a strong influence on the student learning motivation. The grading has to be open and well connected to the intended course outcomes. John Biggs has classified the different levels of understanding [2], which suits well as a basis for reflective learning journal grading.

3 LEARNING JOURNALS IN PRACTICE

We have used various versions of learning journals depending on the course level and teachers' working habits. During a basic Bachelor level course in the first year of studies, the students are not yet capable of proper self-reflection. It is anyhow already important to familiarize the students with the basics of learning journals and the writing process. Due to the high number of students participating in these courses, proper analysis and grading of all the learning journals would result in an impossible work load for the teacher. A few possibilities for reducing the teacher's workload were discussed in the previous section. In the basic course case presented in this paper learning journals were used in a fairly limited way. The students were familiarized to the writing process with the help of learning journals. The process also empowered students own thinking.

Weekly journal entries provided an important feedback channel to the teacher providing information about which topics were understood by the students and which were difficult. This information was effectively used during the following lectures, when recapturing the previous week's most important topics.

New engineering students in a large class are commonly quite reluctant for active participation and discussion. The feedback channel from the students to the teacher provided also an easy way to encourage the class for open discussion of the course topics. The discussion enhanced the metacognitive skills of the students. Many students improved clearly their self-reflection in the next journal entries by analyzing their own thinking on the previous week.

As the students had just started their university studies, the self-reflection capabilities were expected to be fairly limited. The grading of the learning journal was selected to be only as pass or fail, with a quite low threshold. This reduces remarkably the teacher's workload. The numerical grade of this course was based on a traditional exam.

In advanced master-level courses the students are expected to have, in addition to substance knowledge, also some metacognitive skills. As the number of students participating in these courses is lower than in the basic courses, the teacher has better possibilities for evaluation of the learning journals and providing personal feedback. The students are encouraged to critical thinking of the course topics and their own learning process.

The following list is given to students in advanced courses as guidelines for writing the journals:

Learning journal is essentially about critical reflection of the things you learn during the lectures. Don't write merely a summary of the lecture or seminar presentation, but rather

- bring out points that you found especially interesting,
- comment on ideas presented by the lecture,
- bring out questions the lecture raised in your mind,
- ponder what were new pieces of information or viewpoints to you,
- ponder whether the ideas presented corresponded your preconceptions or not,
- reflect on whether the lectures changed your thinking on the issue in some way.

In advance courses the learning journals are used for grading the courses without exams. Separate exercises are used with a possibility for improving the grade based on the learning journal. The final learning journal has to be written in master's thesis style, preparing the students to the writing of their thesis. The grading of the learning journal is based on the university's assessment criteria for the master's thesis [3], with suitable adaptations. The modified assessment criteria are presented in Table 1.

TABLE 1. Assessment criteria (1-5) used in all courses.

1	Sufficient	The learning is modest in terms of scientific questions.
2	Satisfactory	The learning journal is limited in scope.
3	Good	The target level of the course. The learning journal contains all relevant topics presented during the course.
4	Very Good	The learning journal contains the author's own observations or independent evaluations
5	Excellent	The learning journal demonstrates an independent, critical and innovative approach to the topic.

4 CASE STUDY

The case study is made on an annual basic course. The course has had a similar structure for already several years, and learning journals were taken in use in this course during spring 2012 to strengthen and support students' learning while expecting students to reach higher grades than in previous years. A comparison of two consecutive course implementations, one with learning journals used and another without them produces interesting numerical material for evaluating differences in learning results between the two instances.

The course is part of obligatory basic engineering studies, targeting the first year in the university. This course has typically about 70 students participating the lectures. The course is based on lectures, exercises and an exam. In order to pass a course, a student must have solved at least 50% of exercises. Students who do more of the exercises will have a bonus of up to 1 grade in their course assessment. Students have three opportunities for taking the exam. Each exam has similar structure and equivalent questions. The grading is based on the achieved exam points. Minimum (grade 1) pass requires at least 15 exam points of maximum 30. The contents, exercises and exams were similar in both years, but two changes were made in the course requirements. Previously, in the supervised exercises the student marked himself the exercise problems he had solved. In the 2012 implementation the students returned electrically their answers before the supervised exercises. The biggest change in the 2012 implementation was the new requirement of returning an obligatory learning journal.

TABLE 2. Comparison of results of the same course without (2011) and with (2012) learning journals.

	2011	2012
Participants (showed up at least once)	75	70
Students in exams 1-2	50	44
Passed	29	32
Passed (%)	58,0 %	72,7 %
Average exam points	15,2	17,8
First timers in exams 1-2	37	31
Passed	22	23
Passed (%)	59,5 %	74,2 %
Average exam points	15,2	18,4

Due to targeting first year students with very limited metacognitive skills, the learning journal was graded only as pass or fail, with a very low threshold. The students returned their weekly 0.5–1 page learning journal entries. By reading random 10–20 returned journal entries, the teacher was already very well aware of which topics were learned well, and which topics required additional recapture during the next lectures. Also, the questions, ideas and sometimes misunderstandings in the learning journals provided an inexhaustible source of topics for fruitful active discussions during the next lectures.

Table 2 has a comparison of exam results for the two years. Number of participants is based on a list of attendance in lectures. This list was useful also for analysing a topic which was found to be difficult. It was easy to check if the issue was in teaching or in the student participation.

After the lectures and exercises the student has three possible exam dates. The student is allowed to participate in the next year exams if none of the dates is suitable, or if he fails the last exam of that particular year. At the time of writing this paper, only two of the 2012 exams have taken place. In order to keep the comparison justified, the results of the third exam of 2011 have been excluded from the statistics data.

Some of the students have participated in the lectures of the previous years, and taken the exam on the year after. First timer was defined as a student who had not been participating in supervised exercises in previous years (2010, 2011), thus writing the obligatory learning journals in 2012 implementation.

233 WEB 2.0 AND COLLABORATIVE LEARNING: AN APPLICATION ON INDUSTRIAL ENGINEERING COURSE

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ABSTRACT

The internet represents a paradigm shift because it allowed the use of computer in collaborative work. An example of this phenomenon is the blog, a web 2.0 tool. Web 2.0 tools have changed the way that internet users interact on the network. Accordingly, this paper discusses the question: "How professors can improve collaborative learning through web 2.0 tools inside of engineering education?" To answer it, this paper focus on an experiment developed in a discipline of an industrial engineering course. The blog was chose for this research, because it represents collaboration, autonomy and authorship. The activity proposed claims to develop students' collaborative abilities in learning process. We conclude that is possible to create a motivational space using collaborative strategies in engineering education. This does not means deny the importance of expositive classes, but it shows how the collaborative methodology can be used allied to traditional learning model. This activity fosters a large interaction and participation of students' in classroom and each work group had the possibility to interact with the others groups and enterprises\professionals engineers outside the University.

Keywords: Collaborative learning, Web 2.0, Engineering Education.

1 INTRODUCTION

The diffusion of communication and information technologies stimulated a new way of thinking the learning process, called collaborative learning [1]. This fact was driven by the development of internet, in which the concept of Web. 2.0 represents a paradigm shift by interaction viability. The Web 2.0 tools changed the way the internet users interact on the network. This evolution affects the pedagogical models, influencing how people organize and share knowledge. The interaction can be considered a new form of thinking the learning process, in which the ideas are constructed by a group discussion on the network.

The contact of students with communication and information technologies is being raised by interaction tools, a fact confirmed by the increasing use of social networks and blogs, and other resources. The question discussed in this paper is: "How can professors generate a motivational space in classroom using the Web 2.0 tools in engineering education?"

To improve this discussion, this paper focuses on an experiment developed in a discipline of an industrial engineering course from a Brazilian Federal University. The first step is to contextualize the case.

The group of students analyzed in this research is composed of Industrial Engineering students who have previously concluded Science and Technology bachelor degree. These students attend the professional disciplines just at the fifth semester. This fact creates a problem to engineering courses: lack of understanding by students about an engineer's professional life. It also creates a demotivation environment, enhancing the possibility of circumvention. Trying to solve this problem, this research developed an experiment based on collaborative learning with students of industrial engineering fundamentals discipline to promote the students' motivation to the other disciplines of the course.

This paper is structured on three parts: the first presents the concepts of learning, motivation and collaboration, discussing how the Web 2.0 tools can collaborate with the learning process. The second part shows the methodology used in this research. The last part presents the results of this study and the conclusions.

2 LEARNING, MOTIVATION AND COLLABORATION

The Science is not capable to answer how the brain changes when we learn. We suppose that there should be any modification in the nervous system, whose nature has not been fully clarified yet. Accordingly, the learning process is indirectly studied through its effects over the environment.

The engineering teaching must be thought on a less traditional way (sender-receiver model) and adopt a new approach, the progressive, according to which the student constructs his concepts based on the discussion and interaction [7]. In this process, learning is not performed in an individual scope, but it is affected by social and environmental elements [12].

The learning process can not be separated of these elements (environmental, cultural and social) and must be observed in teaching strategies. These elements are called the "Development Domain" and are showed in Figure 1 [12]. To be successful in the learning process, methodologies must observe these domains.

FIGURE 1. *The Four Domain Development Diagram.*

Source: Vanasupa et al. (2009)

In Figure 1, four development domains are illustrated. The first is called cognitive and it is associated to the capacity of processing the information. The second one is called psychomotor and it is associated to abilities gotten by individual practices [12]. These two first factors are considered "internal factors" of the construction of learning.

We can also observe in Figure 1 the "external factors" associated to learning by the external influences and interaction. They are called the social and the affective domains [12]. These domains are extremely important to the learning process [10].

The internal factors are connected to the traditional engineering teaching model, which is focused on the technical area and requires from students much study and the development of work methods. The external factors are seen like the new engineering abilities, characterized by engineers with critical thinking and understanding of the social and economic context.

These four domains are not the only elements necessary to be successful in the learning process. There are the constructs connected to motivation of students to learning. The first construct is called interest, which is associated to the capacity of fun and pleasure in work development. The second is the value, which is linked to the students' beliefs and evaluation as to the content value to their lives. The last one is the autonomy, like the evolution of interest, in which the student goes beyond from material available by the professor [12]. These ideas are linked to Learning Theory of Vygotsky: the development and the learning occur through the acquisition of content through social exchange, for example the exchange of information among people [10].

2.1 Collaborative Learning by Web 2.0 Tools

The collaborative learning is pedagogical strategy which the students must interact to each other and to the professor and be partners in the learning process [1]. This model encourages students to learn together [5].

There are three types of learning: the collaborative, the competitiveness and the individual one. The collaborative learning develops the critical thinking, the confidence and improves the skill in interpersonal relationship [5]. This kind of learning is linked to external factors (social and affective) proposed by [12].

The key issue to success in this learning model, therefore, is related to autonomy, and the professor must stimulate students to develop activities in this way, promoting the interaction [12].The partnership, here understood like interaction, is a necessary ability in contemporary curriculum [4]. Thus, professors must develop this ability in students in order to form engineers with this competence.

In many schools, the participative methodology helps children, youths and adults' learning and other experiences.

Despite the widespread dissemination of these methodologies, transposing this concept to engineering education is not an easy task, because the professor must change his attitude in classroom and guide the students' learning. He is not the "holder of the knowledge". This represents the paradigm shift in engineering education [2]. To make this process easier, the professor can use tools to stimulate the autonomy. There are many tools to support this process and we can highlight the Web 2.0 concepts and tools. These tools are based in collaboration concept.

2.2 Web 2.0 and Education

The Web 2.0 can be defined as the second generation of online services which amplify the spaces of interaction between different people in the form of sharing, publishing and organizing information on the network. These online services characterize the contact with much information and different languages inside the cyberspace. The cyberspace is a place where the learning process happens freely and the student has the autonomy to learn what is of his/her value and interest [11, 3].

In this second stage of web, the participation is stimulated and it generates a great information and knowledge output. This potentiality can be explored in the education context through spaces for processes of collective work, production and circulation of information and social construction of knowledge supported by information technology. In this sense, there are many tools that can help in this process, such as the tools of Web 2.0. An example of a Web 2.0 tool is the blog.

The blogs are web pages chronologically organized like a diary. On this page, it is possible to post images, texts or other files [14]. There are spaces for users' comments and the reader can discuss with the blog author. This kind of resource promotes interaction and collaboration between users. In this case, the readers are authors too, proposing their ideas and complementing a concept [11].

Because of its possibility of interaction and collaboration, the blogs are used for many objectives: personal diary, entertainment and pedagogical practices, and other uses. It is important to highlight that the blog is a democratically and valued space for the collective construction of knowledge and this is available on the network to other internet users.

In the blog, the student presents a more reflexive attitude and contextualizes the subjects presented with other sites of web (hypertext). He/She can interact better with other students and with the professor, and get an active attitude in the learning process [13]. There are some elements necessary to make the blog a potential tool for education [6].

- The students must stimulate the other students to discuss the concepts developed in the blog to generate a feedback, resulting in the students' auto motivation;
- Use different forms of communication, like videos, images, texts, audio, and other tools.

The blog is a space of information access constructed by students and it creates a sense of autonomy (key concept proposed by [12]). On the other hand, it works like a space to interchange, discuss, integration and collaboration. The blog can also be used to promote the students' sense of responsibility on their work and the sense of contribution to the world because their production is available on the network [9].

3 METHODOLOGY DEVELOPED IN RESEARCH

This research presents qualitative elements because it searches to understand a phenomenon by description, decoding, translation and interpretation of a process [8]. Figure 2 presents the steps of the research based on the qualitative method of participant observation. This method uses documental analysis, interviews, participation, direct observation and introspection to get the data. It is necessary for the researcher to be an element, a participant in the research and observe the impact of his/her influence in the studied process.

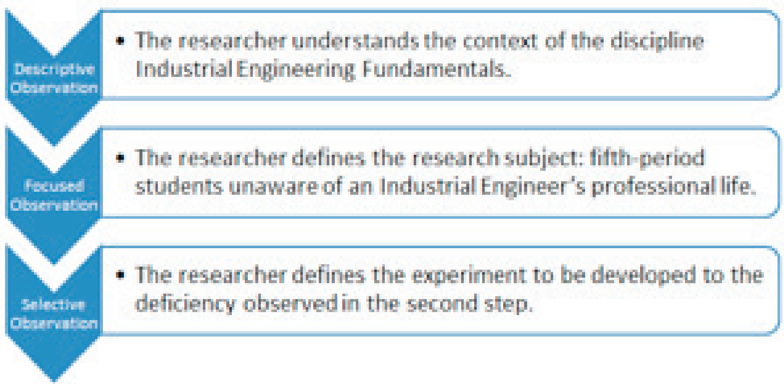

FIGURE 2. *Research method developed.*

The first step of this study, the descriptive observation, analyses the methodology used by professor and the course of the discipline. To have this information, a questionnaire with open and closed questions was applied with students to understand the general context of the discipline of Industrial Engineering Fundamentals. Based on the answers obtained in this questionnaire, it was defined that the focus in this study is the group of students enrolled in the discipline industrial engineering fundamentals.

An activity was proposed to the group aiming at improving the concerning of students on the action areas of an industrial engineer. The students were separated in ten groups of two people.

The idea proposed was the creation of a blog and the students would be the authors of the blog contents. This first group was responsible for the blog creation on the network. Also, they were responsible for the following activities:

- Historical Survey of Industrial Engineering;
- Developing a mental map listing all the areas of Industrial Engineering;
- Presentation of reports and interviews about the role of Industrial Engineer in the organizations.

The other groups were responsible for each area of Industrial Engineering defined by the Brazilian Association of Industrial Engineering and they had to present some topics about these themes:

- How the area emerged;
- Each topic of the area;
- Interview an engineer who works in the researched area to identify his activities;
- Examples of applications of the tools related to the studied area. Each group must follow the steps: problem presentation, the tools used to solve the problem; the solution obtained with the application of the tool and evaluation of the benefits and problems of the tool application to solve the problem.

The objective of the activity was to stimulate a more active attitude in students in the learning process and instigate their investigative instinct. This activity created a space to observation of the students' attitudes in the proposed activity. It was also observed how the external factors, proposed by [12], are influenced by the concepts of collaborative learning, proposed by [1], by using the blog and its potentialities (responsibility sense by producing the blog material), proposed by [9].

4 RESULTS

The entrance to engineering courses at the Federal University of Semiarid (UFERSA) happens after the students have the Science and Technology bachelor degree (Bacharelado em Ciência e Tecnologia – BC&T). In this course, students do not have much contact with engineering and they attend only the basic disciplines, like chemistry, math and physics. However, in the fifth period of the BC&T course, the students attend disciplines from the engineering courses which they plan to enter. This is the case of the discipline Industrial Engineering Fundamentals.

It is observed a separation of content presented in classes with the engineering professional practice, and the students do not understand the importance of the basic disciplines to the engineers' formation. This represents a possible source of demotivation. It was identified the most cited reasons for students to choose the Industrial Engineering course. The three most important reasons are: comparison to other engineering courses in UFERSA, job opportunities and connection with the profession. The students do not know the industrial engineer's professional life.

It can be observed, however, that most students did not know the industrial engineering course. This illustrates how ignorant they were when choosing the course. It can be observed that most students did not understand an industrial engineers' function in industry. Thus, the students do not connection with the course and there can be a sense of demotivation in students because they do not understand the importance of the disciplines.

It is important to highlight that the students told they know what an industrial engineer does. However, the professor found that the students have a superficial concept about the industrial engineers and they just exhibit the name of some tools used by this professional. They do not understand the holistic view that this engineer represents in an organization. This showed the necessity of developing this knowledge in students. Table 3 illustrates the students' statements about an Industrial Engineer.

TABLE 1. Statement characteristic of students about the activities of an Industrial Engineer.

Superficial definitions	Definitions related to specific areas
"This engineer is a problem solver..." (Student 1) "He/she works in production of goods and services..." (Student 6) "He/she can work like a manager in some industry areas..." (Student 12) "He/she supports decision making..." (Student 15)	"He/she works in the demand forecast, making decisions related to production..." (Student 8) "...checking if the production process can be optimized..." (Student 19) "...programming the production line..." (Student 20)

According to this result, the professor developed an activity to stimulate the interest of students to know the industrial engineer's function in industry. There is a wide-ranging content and the students did not have previous contact with the industrial engineering world. Accordingly, the professor chose working with these contents using the collaborative learning methodology in order to develop an autonomous attitude in students. However, to achieve this goal, the students must be motivated to the development of the work proposed. In the sense to develop the motivation, the mainspring of learning [12], the professor developed an activity based on the field research using an interactive Web 2.0 tool: the blog. Initially, the first group created the blog, available at http://engproducaoufersa.blogspot.com/. Figure 3 illustrates it.

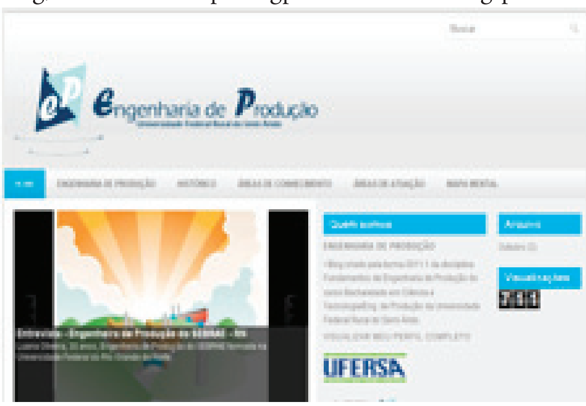

FIGURE 3. *Blog developed by the students*

Source: http://engproducaoufersa.blogspot.com/.

It was observed effort and care in creating this blog. The students created many tabs to each industrial engineering area and they did interviews with engineers.When we analyzed the developed blog, it can be observed that it works like a pedagogical strategy, assuming the role of a digital portfolio with the contribution of each group. The blog integrates the students' different ideas. It characterizes the pedagogical use of blog.

The material developed by the students was prepared based on different media (videos, texts, images, audio, and other resources) and made available on the blog by link indications. This allowed the blog reader to trace his/her own path of reading, based on the link choice. This illustrates the form of the blog use proposed by [14].

The sense of contribution and information sharing beyond the classroom was created in the student. This blog is being published to clarify BC&T students who did not make their choice by an engineering course. This form of disclosure of the blog created the sense of responsibility, proposed by [9] because the material prepared is available on the network. It can be observed that the students had performed a big research. In this point, the activity proposed allows students to improve their work by the imagination and organize their ideas the better way.

The activity proposed allowed a better learning, comparing to traditional classes. The students were encouraged to make their contribution available and spread the results found. This makes it possible the creation of a motivational environment through the three elements proposed by [12] and the interaction among students.

5 CONCLUSION

The development of this research allows demystifying some points in engineering education. Initially, the collaborative strategy stimulates a motivational environment. However, this does not mean refusing the exposure of the contents by the professor, but it shows that the strategies can be used together to maximize the learning process.

The methodology developed in this research allows the professor to develop the students' curiosity and promote their active attitude. This created an auto motivational environment and facilitated the learning process. Another benefit of this experiment was the availability of the knowledge constructed by students outside the university and the blog was very good for this purpose.

There is a big potential of this pedagogical strategy application in other engineering courses. This strategy, however, is difficult to apply for the need to form professors in these technological tools and for they must change their attitude in the classroom.

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236 TEACHING ULTRASONICS USING SPREADSHEETS

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ABSTRACT

Whenever an ultrasonic wave encounters a boundary between two media it is partially reflected and refracted, as any acoustic wave would be. Unlike light, the wave also undergoes mode conversion so that in the general case a single incident wave could produce two reflected waves and two refracted waves. The angles which define the path of the wave are determined by Snell's law and are easily calculated. The relative amplitudes, on the other hand, require quite complicated formula when the angle of incidence is anything other than 0 degrees. This problem gets compounded when the angle of the incident wave goes beyond the first critical angle. At this point the angle of the refracted wave becomes imaginary and the equations to calculate the relative amplitudes become complex. This paper describes a tool that has been developed, using a spreadsheet, which performs the calculations for all incident angles. The user selects the media and the type of incident wave and the resulting waves are shown graphically as well as numerically. The tool was developed primarily as part of an undergraduate course on ultrasonic testing, but could be used more widely.

Keywords: Ultrasonics, spreadsheets, complex angles.

1 INTRODUCTION

Any course on ultrasonics or ultrasonic testing has to include the behaviour of waves at boundaries. Most courses or textbooks on ultrasonics (or acoustics in general) [1,2] will show waves at boundaries being reflected, refracted and mode converted. In the general case, shown in Fig. 1, the incident wave could be compressive (longitudinal) or shear (transverse). At the boundary, mode conversion takes place which means that there is a reflected compression and shear wave, and a refracted compressive and shear wave.

The angles of the reflected and refracted waves are calculated using Snell's law. So:

$$\frac{c_{1c}}{\sin\theta_{ci}} = \frac{c_{1s}}{\sin\theta_{si}} = \frac{c_{1c}}{\sin\theta_{cr}} = \frac{c_{1s}}{\sin\theta_{sr}} = \frac{c_{2c}}{\sin\theta_{ct}} = \frac{c_{2s}}{\sin\theta_{st}} \qquad (1)$$

where cpq is the velocity of the waveform in media p and type of wave q ('s' for shear or 'c' for compression) and θqr is the angle from the vertical for wave of type q and r (where it can be 'i' for incident, 'r' for reflected and 't' for transmitted).

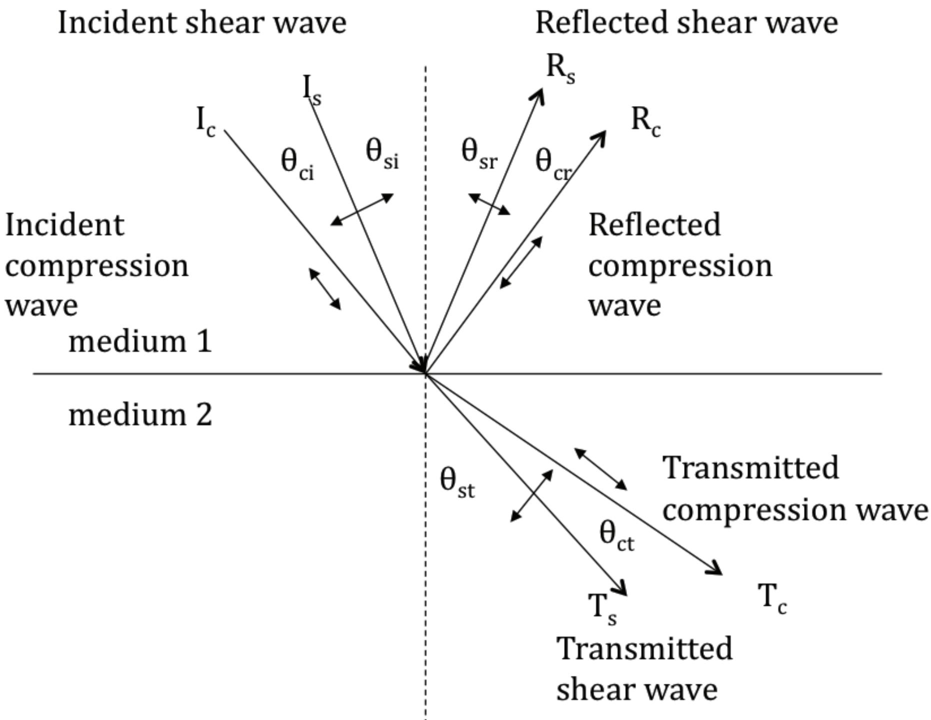

FIGURE 1. *The general case of an ultrasonic wave at a boundary.*

The next step is to find the amplitude of the reflected and refracted waves. Most books give the equations for the relative sizes of the waves only when the incident wave is at zero degrees i.e. orthogonal to the boundary. In some of the more advanced books, equations are given for the relative energy or amplitude up to the first critical angle, but not beyond. The reason for this is that the equations become complex, i.e. have real and imaginary parts [3], after the first critical angle, and for the beginner in ultrasonics this is too much to handle.

Previous work [4,5] has shown how these equations can be calculated using Excel spreadsheets. These spreadsheets were chosen because most students have access to Microsoft Office, and therefore there is no need to purchase or learn to use bespoke software. The previous papers showed how a spreadsheet can be used to produce plots of the relative amplitude/energy with respect to the incident angle, or in a different spreadsheet how matrices can be used to calculate the relative amplitude/energy for a specific angle. In this paper the same spreadsheet will be used to solve the underlying equations. Feedback from students was received about the original spreadsheets, where the output showed a graph of the amplitudes/energies plotted against incident angle. The students were expected to read from these graphs to get solutions to specific incident angles. They also said that they found it a little difficult to picture the problem. A new graphical output was developed to provide a simple visual interpretation of the problem, and give the solution to a specific incident angle.

1.1. Matrix Solution

The relative amplitude can be calculated using matrix notation for which only one equation is used.

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{bmatrix} R_c \\ T_c \\ R_s \\ T_s \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \end{bmatrix} or \begin{bmatrix} c_1 \\ c_2 \\ c_3 \\ c_4 \end{bmatrix} \quad (2)$$

The [B] matrix is used if the incident wave is compression, whereas the [C] matrix is used if the incident wave is shear. The elements of the matrices are shown below.

$$[A] = \begin{bmatrix} -\cos\theta_{c1} & -\cos\theta_{c2} & -\sin\theta_{s1} & \sin\theta_{s2} \\ -\sin\theta_{c1} & \sin\theta_{c2} & \cos\theta_{s1} & \cos\theta_{s2} \\ -Z_{c1}\cos 2\theta_{s1} & Z_{d2}\cos 2\theta_{s2} & -Z_{s1}\sin 2\theta_{s1} & -Z_{s2}\sin 2\theta_{s2} \\ -Z_{s1}\frac{c_{s1}}{c_{c1}}\sin 2\theta_{c1} & -Z_{s2}\frac{c_{s2}}{c_{c2}}\sin 2\theta_{c2} & Z_{s1}\cos 2\theta_{s1} & -Z_{s2}\cos 2\theta_{s2} \end{bmatrix} \quad (3)$$

$$[B] = \begin{bmatrix} -\cos\theta_{ci} \\ \sin\theta_{ci} \\ Z_{c1}\cos 2\theta_{si} \\ -Z_{s1}\frac{c_{s1}}{c_{c1}}\sin 2\theta_{ci} \end{bmatrix} \quad (4)$$

$$[C] = \begin{bmatrix} \sin\theta_{si} \\ \cos\theta_{si} \\ -Z_{s1}\sin 2\theta_{si} \\ -Z_{s1}\cos 2\theta_{si} \end{bmatrix} \quad (5)$$

To find the values of the reflected and transmitted waves, the [A] matrix needs to be inverted.

$$[A]\begin{bmatrix} R_c \\ T_c \\ R_s \\ T_s \end{bmatrix} = [B] \text{or} [C] \quad (6)$$

$$\begin{bmatrix} R_c \\ T_c \\ R_s \\ T_s \end{bmatrix} = [A]^{-1}[B] \text{or} [A]^{-1}[C] \quad (7)$$

The inversion is carried out on Excel as described in a previous publication [5].

2 GRAPHICAL REPRESENTATION

2.1 Relative Energy

Although the spreadsheet calculates the relative amplitude and energy of all the waves at a boundary, it is much easier to interpret the situation using graphics. The choice of graphics in Excel is quite wide, such as line graphs, bar charts, pie charts, and scatter diagrams. To illustrate the relative energy it was worth noting that as no energy can be created or destroyed, the energy of the incident wave must equal the sum of the energy of the reflected and refracted waves. As we have calculated relative energies, that is the energy of the reflected and refracted waves divided by the energy of the incident wave, the sum of the relative energies should be 1 or 100%. Therefore, a pie chart which shows how the 100% is divided among the reflected and refracted waves is a good choice. Figure 2 shows a typical result.

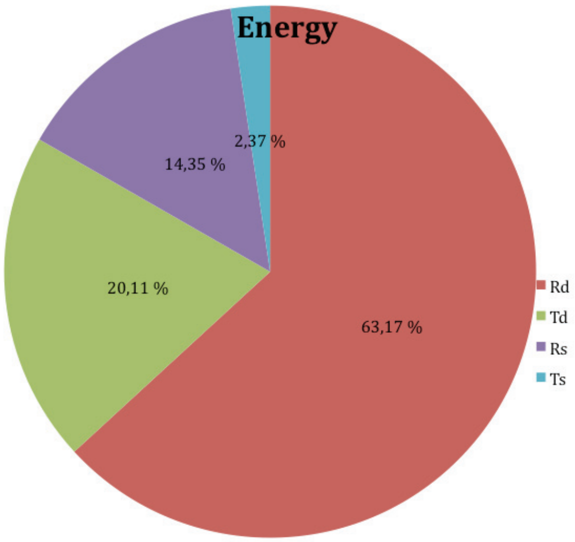

FIGURE 2. *Relative energy shown as a pie chart.*

The pie chart shown in Figure 2 shows the relative energies of the reflected and refracted waves as percentages and as coloured segments. In this example the incident wave is a compression wave at an angle of 20 degrees at a boundary between Perspex and Inconel 625, a steel alloy. It shows the relative energy of the reflected compression wave, Rd in red, the reflected shear wave, Rs in purple, the transmitted compression wave, Td in green, and the transmitted shear wave, Ts in light blue.

2.2 Relative Amplitude

Since the angles of the various waves can be easily calculated, and in fact have to be calculated as part of the bigger calculation of the relative amplitude, it makes sense to use them in the graphical display of the relative amplitude. The decision was made to show the waves as a vector, with the angle of the vector corresponding wave, and the length of the vector corresponding to the relative amplitude. First, a table had to be constructed with the coordinate pairs for the beginning and end of each vector. Then the plot could be created, as in Figure 3.

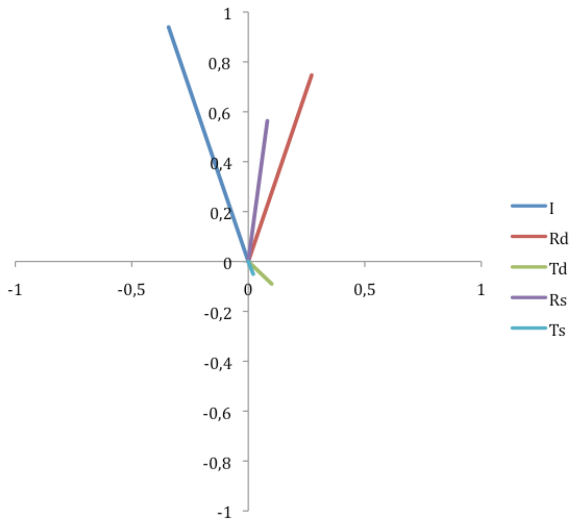

FIGURE 3. *Relative amplitudes shown as a linear vector plot.*

The plot in Figure 3 corresponds to the same set up as in Figure 2. The incident wave is shown in the top-left quadrant, while the reflected waves are in the top-right quadrant, and the transmitted or refracted waves are in the bottom right quadrant.

3 ADDITIONAL FEATURES

As well as the graphical display, some additional features were added to the original spreadsheets to make it easier to use. The first was a drop-down menu to select the type of incident wave, compression or shear. The second was a slider input for the angle of the incident wave. This means that the incident angle can be selected using the slider in steps of 1 degree, or a specific angle can be entered directly into the box. These features are shown in Figure 4.

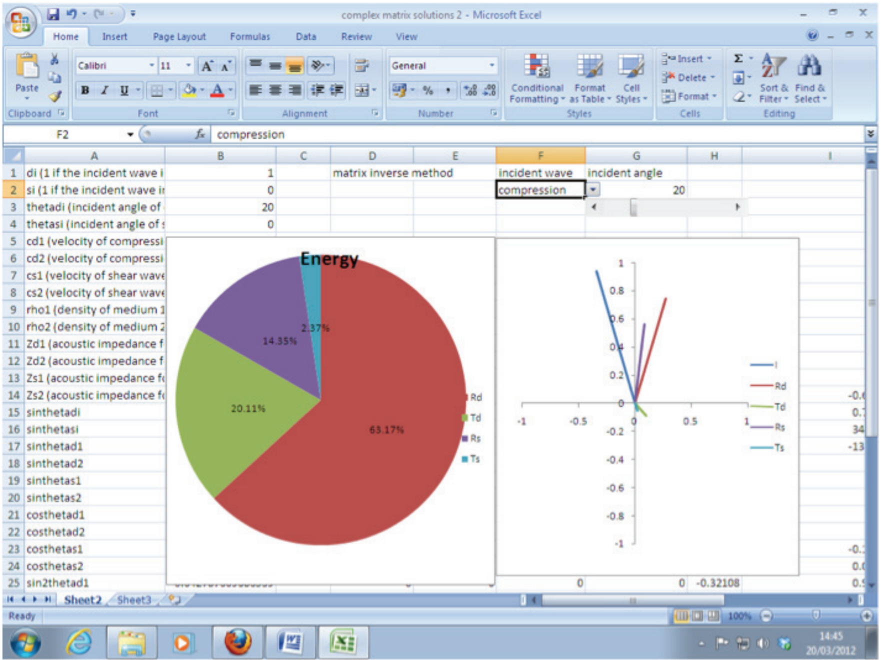

FIGURE 4. *Whole spreadsheet showing additional features.*

5 CONCLUSION

This paper has developed a spreadsheet application in which all the ultrasonic waves at a boundary can be calculated, both the relative energy and amplitude. However, for teaching purposes, and indeed applications to real-world situations, a visual display of the results is more effective. The relative energy can be displayed as a pie chart which then easily shows the relative amount of energy in each of the reflected and transmitted waves. In addition, the relative amplitude and angle is displayed as a vector diagram, which incorporates the angle of reflection/refraction with the relative amplitude. So far, students have given favourable comments about the new spreadsheet and have found it useful both in learning about ultrasonics and in real-world applications.

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237 PROMOTING KNOWLEDGE SHARING AND INNOVATIVENESS IN E-LEARNING ENVIRONMENT

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ABSTRACT

The special character in ICT companies lies in that they are knowledge intensive, operating usually in international markets and they have to be able to utilize and create new knowledge constantly to remain competitive. This article examines what kind of features and processes in e-learning environment support dynamic co-operation, information flow and innovation creation especially in a multicultural and multinational project environment. The chosen methodology here is case study. Exploitation of e-learning environment with complex communication tools was seen to support knowledge and project management in many ways. The evident advantages were transparency in project management and product development, efficient risk and change management and efficient information dissemination and storage. Cross-cultural collaboration requires active use of multiple communication channels. The use of e-learning environment was not perceived as able to compensate totally for the need for face-to-face meetings but it was seen to reduce the number of the meetings.

Keywords: Knowledge management, e-learning environment, knowledge sharing

1 INTRODUCTION

The ICT business sector is growing and developing rapidly. The special character of ICT companies lies in that they are knowledge intensive, operating usually in international markets and they have to be able to utilize and create new knowledge constantly to remain competitive. The only sustainable competitive advantage is continuous innovation [1]. This requires efficient knowledge management practices and a place where knowledge can be shared, stored, and created.

To contribute to the area of interest, we will discuss about a statutory e-learning environment in successful collaboration for small ICT companies and in more detail which factors in collaboration and in e-learning environment support dynamic co-operation, information flow and innovation creation especially in a multicultural and multinational project environment. More specifically, we examine how information flow can be promoted in an e-learning environment, how feelings of trust and rapport can be created without face-to-face communication and whether face-to-face communication is essential for successful collaboration. This article will present and model findings of selected information rich case studies. The topic is important when knowledge intensive companies are trying to find approaches to improve their performance to remain competitive and at the same time, when developing different type of e-learning environments for educational and commercial purposes.

The paper is structured as follows: Section 2 will present the special characteristics of the ICT business sector and creating innovation creation in the field as well as discuss about knowledge management in the context of e-learning environment. Section 3 presents the chosen methodology. Section 4 reports the findings from the case studies. Finally, Section 5 concludes our study and suggests further research.

2 BACKGROUND

2.1 ICT-business sector and characters of innovations

Finland has a very strong ICT sector. It is largely the outcome of mutually enforcing, dynamic cluster relations which were intensified during the 1990s. Nokia has had a significant role in ICT development in Finland. Finnish ICT companies are mainly focusing on developing software [2]. The profitability of the ICT industry weakened significantly in 2000 and since then finding external financing (venture capital) became more difficult. The difficult financing situation has harmed the development of the ICT industry. However, most important development areas have been increasing the degree of productization and are creating value-added services. Companies with high degree of productization had in 2004 the highest profitability expectations. Especially in Finland, the internationalisation of ICT companies is still at relatively early phase. Increasing the degree of productization and making product management more efficient are two of the key-factors for Finnish firms for successful operations in the international markets [3, 4]. Most ICT companies carry out R&D work and product development internally. Outsourcing such activities is quite rare though it is common that the companies have joint research and development projects with other similar enterprises. In addition, customers are usually strongly involved in the development process. ICT companies are active in networking and the nature of co-operation is mainly horizontal. [2,5.].

2.2 Knowledge management

Kuusisto, Kulmala & Päällysaho [6] researched small and medium sized knowledge intensive companies in Finland and the UK attempting to understand how small companies manage and protect their intellectual property. Half of the interviewed software company managers in both countries emphasized the importance of free information flow and efficient knowledge dissemination in the company. The perceived importance of free information flow in the software sector, may relate to the fact that new software innovations are often born spontaneously on 'ad hoc' basis, incrementally and in co-operation amongst employees, collaborators and the client. This type of process requires efficient information flow within the company. Real life for many companies in the 21st century is that clients, collaborators and even employees are not located on the same physical premises. Knowledge management promises to improve company performance by using technology to store and disseminate knowledge [7,8]. The eminent part of knowledge that exists in the company can be stored in a variety of ways with access for all employees or project participants [9]. However, most of the companies are still using mainly traditional ways to communicate with each other such as teleconferences, skype, e-mail, face-to-face meetings and combinations of the previously mentioned methods. Even though ICT company managers emphasize free information flow and efficient collaboration and are on the front-line in technological development, only a small portion of the companies are using different kind of e-platforms for internal and external communication and collaboration [7].

Nevertheless, true improvement in information exchange and knowledge utilization demands more than simply putting more information into databases [7]. A great deal of companies' knowledge is embedded in practice and is tacit from its nature [10]. Tacit knowledge is mostly embodied in individuals, systems, routines, practises and processes [6]. Tacit knowledge develops from the transfer of context-specific knowledge embedded typically in non-standardized and tailored processes [11]. To utilize tacit knowledge, it needs to be either communicated in face-to-face discussions and/or codified in explicit, easily transferable form. This process requires from individuals motivation to share knowledge and on a company level, a place, physical or virtual, where knowledge can be shared and stored, and inside built mechanisms or processes that steer work processes in the company. According to Yang (2007) when sharing knowledge is successfully evolved, new tacit and explicit knowledge in the forms of routine tasks and competencies are often implemented in the company but if the company does not implant a mechanism or process for storing what employees have collectively learnt, effects are not long-lasting [12]. In addition to benefiting from tacit knowledge, one must be able to interpret, internalize and understand it [7]. This becomes challenging in an environment where co-workers are not physically located on the same premises and do not know each other in advance. Codifying a message for transmission e.g., sending information via e-mail, involves loss of information especially when the receiver does not associate in the same cluster of meaning. Inter-company and especially cross-cultural communication requires simultaneous activation of several channels of communication [7]. Taken together, many components affect the effectiveness of tacit knowledge sharing e.g., the amount and style of interaction, language and proximity. In addition, factors such as commitment, trust between the people involved, leadership style and organization culture have also a critical influence on the success of utilization of tacit knowledge in the companies.

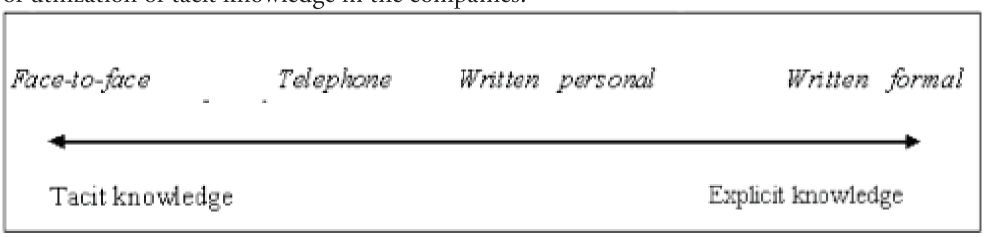

FIGURE 1. *Media richness vs. externalization of tacit knowledge [7].*

E-learning environment in this study is defined as any platform which is being used from a web browser and is limited to the use of a certain group or whole company and the communication is two-way.

3 METHODOLOGICAL APPROACH

The chosen methodology here is case study. A case study allows an investigation to retain the holistic and meaningful characteristics of real-life events, in other words, to obtain in-depth information of the research target in its own context. The software companies included in this research are software product businesses. Case studies were selected by using snowballing to ensure the richness of the data. In snowballing the sample is collected by using one respondent to suggest other suitable respondents [13]. The selected companies based their businesses on self-developed software products but the degree of tailoring varied. The selected companies were small, operating in international markets and they had internal R&D work. A special characteristic in small firms is that they are able to respond quickly to changing market demands, are organisationally flexible, and have efficient internal communications [14]. A semi-structured open-ended face-to-face interview format was used as an interview design. The method requires that researcher takes control of the data collection which gives the researcher more analytical control over the material. [15,16.].

4 FINDINGS

The companies selected in the case studies were Finnish ICT companies developing high technology application internally and in co-operation with similar companies. Companies also took active part in publicly funded research project where they were developing application in consortium. The companies were operating in international markets, employing 6 to 15 employees and had been operating for more than 5 years. Figure 2 presents the spiral of knowledge conversion in the context of an inter-company joint-development project. The model and aim of interaction are linked into the SECImodel. The four modes of knowledge conversion were introduced by Nonaka and Takeuchi (1995). The modes are as follows: (1) from tacit knowledge to tacit knowledge, which is called socialization; (2) from tacit knowledge to explicit knowledge, or externalization; (3) from explicit knowledge to explicit knowledge, or combination; and (4) from explicit knowledge to tacit knowledge, or internalization. This model of knowledge creations is applied in this article in order to present and interpret the findings of the case studies.

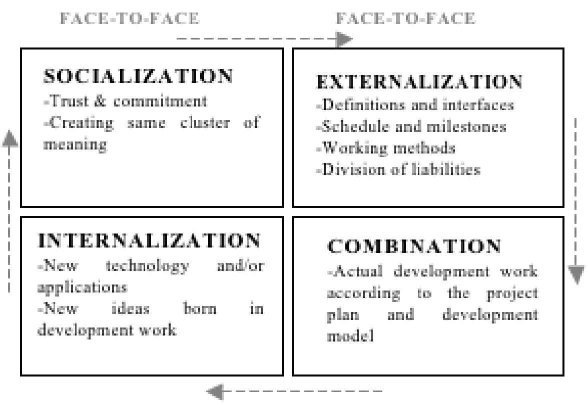

FIGURE 2. *Model for collaboration in context of SECI-model ([17], modified).*

When starting collaboration, a face-to-face-meeting was felt crucial for successful collaboration even though the company would have been using e-learning environment with complex communication tools. Developing trust between the parties and creating common understanding of the project goals, working methods and schedule took place/occurred in the first phases. The presence of key-persons from both sides was a condition. Trust allows access to resources and a willingness and motivation to work things out through mutual problem-solving. Principles for project management including project management tools, communication, steering group, liability distribution and schedule with milestones needed to be defined up-front in face-to-face situation if possible. An up-front defined development process or product development model was seen important for quality management and it also supported the transparency of collaboration and co-production. In international co-operation when the parties were not speaking their mother tong, active communication, face-to-face by choice was important in order to reach the same cluster of mind. Language differences shape meanings and in this way it affects the effectiveness of the process of tacit knowledge sharing. Language differences become even more complex when the information is shared in written form. In the form of written text, the information can be lost due to the meaning differences, lack of body language etc. Ways of working, attitudes, values, communication style and traditions are culture-dependent and must be taken into account in cross-cultural collaboration. As mentioned, gaining the same cluster of mind requires high level of communication and activation of several channels of communication. High levels of interaction face-to-face if possible or through telecommunication and other channels, were seen crucial to gain common understating in the beginning of the project.

Exploitation of e-learning environment with complex communication tools was seen to support efficient communication and project management in many ways. Even though face-to-face meeting was seen as crucial in the beginning of the collaboration, an e-learning environment was seen to compensate for the need for face-to-face meetings when the project has started. Advantages in the use of e-learning environment included transparency of project management and product development when all documentation was in the e-environment, more efficient risk- and change management because problems were identified in the early phases, resource and time management and efficient information sharing and storage. The e-learning environment should include following features in order to work as an efficient tool for collaboration:

- Version management
- High level of data protection
- Shared calendar that is linked to document bank
- Shared desktop and documents
- Audio-visual communication tools
- Operating via web browser
- Basic tools for project management (costs and resources)
- Ability to share applications

5 CONCLUSIONS

The aim of the article was to discuss about a statutory of e-learning environment in inter-company collaboration in the context of small ICT-companies and investigate which factors affect the effectiveness of inter-company collaboration in general. Further this article discussed features in e-learning environments that support dynamic collaboration, information flow and innovation creation in an inter-company, cross-cultural and multinational project environment. The research sample does not allow for genaralization of the results in a statistical manner but it provides in-depth qualitative information of selected cases. The ability to apply shared knowledge to perform important activities more efficiently is increasingly seen as the source of competitive advantage in many industries [18]. Due to the fast development of web-based communication tools [19], companies are able to utilize efficient e-environment tools that allow use of different channels of communication simultaneously with pre-defined groups of people and efficient knowledge repository and company memory. There is no information available on what portion of small companies are actually utilizing e-learning environments or e-platforms. However, due to the evident advantages of the use of e-environments in knowledge and project management and fast technological development, the use of e-environments is highly likely to be growing rapidly in the near future.

FIGURE 3. *Development of knowledge management technologies ([18], modified by present authors).*

Collaborative technologies do exist. In addition to technological development, these technologies should also be focused on human interaction rather than just on information systems. Figure 3 presents a timeline of the development areas. . The direction from information system development towards human interaction can be seen clearly. [18]. The fact that a great deal of the know-how required in implementation of a task is tied to knowledge that is not written but realized through understanding the goal and nature of the work. Active interaction and pre-defined models and work processes foster utilization of tacit knowledge. Besides technological development of e-environments, models and processes of interaction should also be investigated especially in cross-cultural project environments. In today's knowledge economy, efficient and fast access to knowledge is critical to the success of many organizations. ICT provides a broad platform for efficient knowledge management with complex tools of communication and information processing abilities.

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238 TEACHING DIGITAL DESIGN IN THE FPGA AGE

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ABSTRACT

Field Programmable Gate Arrays (FPGA) are today a mainstream of digital design. The complexity of FPGA configuration process calls for the use of Hardware Description Languages and of sophisticated Electronic Design Automation tools and, therefore, today's digital designers must be trained accordingly. We present a new extension of our educational design suite for digital circuits, the Deeds. Using the extension, students may compile a project into an FPGA chip starting from Deeds, leaving in the background the operations performed by the FPGA-specific EDA tool. The extension is specifically conceived for introducing FPGA-based systems in a first course of digital design, avoiding a break of continuity with the pedagogical approach and the tools used.

Keywords: Engineering education, digital design, circuit simulation, FSM, FPGA, HDL, VHDL.

1 FIELD PROGRAMMABLE GATE ARRAYS

Digital electronic systems are, nowadays, ubiquitous in our lives, from consumer products to professional applications. A growing number of digital electronic systems are based on Field Programmable Gate Arrays (FPGA), chips that, after fabrication, can be configured by the designer to implement specific functions and systems. A typical FPGA contains many thousands of simple logic components, and a complex path of interconnections that allows it to be configured to perform all kinds of combinational and sequential functions, even extremely complex ones. FPGAs may contain specialized blocks, such as RAM memories, multipliers etc. and have the capability to include, upon configuration, one or more general purpose processors. Such features make them an ideal vehicle for the implementation of embedded systems. The flexibility offered by FPGA is one of reasons for their growing popularity, in spite of costs still higher than other technologies.

2 LEARNING FPGA BASED DIGITAL DESIGN

The complexity of the FPGA configuration process calls for the almost exclusive use of Hardware Description Languages (HDL) and of sophisticated Electronic Design Automation (EDA) tools. Only in simple systems it is still possible to use traditional schematic entry instead of HDL. Therefore, today's digital designers must be trained for an efficient use of languages and tools. At the same time, they still must acquire a solid base upon which to build their design skills and the ability to adjust to the fast pace of technological innovation.

EDA tools have always played an important role in engineering education, mainly in advanced courses. The changed technological scenario demands now an earlier familiarity with HDL and EDA tools. In fact, there is a strong trend in education to introduce them in a first course of digital design, as exemplified by several new textbooks [1,2]. An added benefit resulting from such approach is the possibility of reintroducing hardware experimentation of digital projects. The educational practice of building breadboards of digital circuits, very popular when the TTL series 74 was mainstream, has become unpractical and it is now adopted only sparingly. FPGA allows, instead, an easy breadboarding and testing of quite complex digital systems by downloading the configuration stream from a PC to a general purpose board hosting the FPGA [3,4]. Manufacturers are keen to encourage that approach, by providing the tools and, sometimes, the boards, free of charge to educational institutions.

Undoubtedly that is a quite effective way to satisfy the need of education to keep pace with professional practices. In our opinion, though, the process calls for some reflections and, possibly, corrections. It is a fact that the use of professional tools and HDL, even in a much simplified form, is not straightforward for the absolute beginners. They may learn how to perform a certain set of operations but they may do that quite mechanically and eschew important basic issues, hidden under the technicalities of HDL and tools. We are convinced that tools conceived to increase the productivity of a digital designer do not necessarily meet equally well the needs of education. Furthermore, a proficient use of HDL requires an amount of programming experience that usually goes beyond the skills of a freshman.

We present here a "middle way" between a traditional pedagogy, based on logical components and schematics, and a contemporary one based almost exclusively on hardware description languages. Our approach is supported by a new feature of the Deeds, the educational design suite for digital circuits developed at University of Genoa (Italy) as part of our research activities in the fields of project based, distance and cooperative learning. Deeds is extensively used by the students of electronic and information engineering, to support laboratory activity.

3 DEEDS: DIGITAL ELECTRONICS EDUCATION AND DESIGN SUITE

Deeds is based on three simulators: the Digital Circuit Simulator (d-DcS), the Finite State Machine Simulator (d-FsM) and the Microcomputer Emulator (d-McE). They cover, respectively, combinational and sequential logic networks, finite state machine design, microcomputer interfacing and programming at assembly level. The simulators can work together, allowing therefore design and simulation of networks including a mix of standard logic, state machines and embedded microcomputers, as today's applications demand.

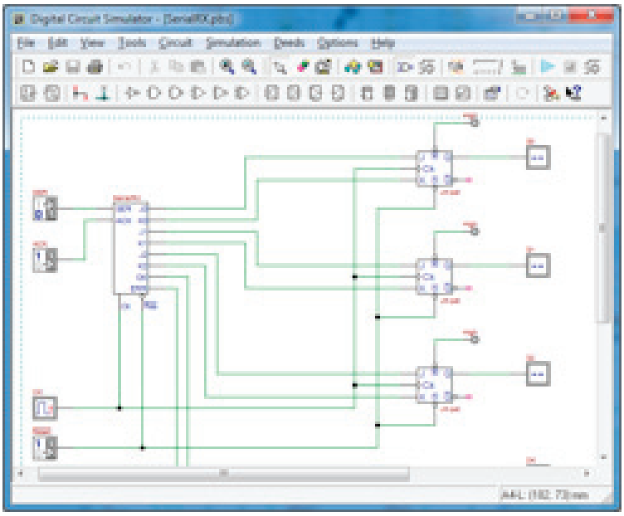

FIGURE 1. *A digital circuit described in the schematic editor of the d-DcS.*

Deeds is integrated with a Main and an Assistant HTML browsers: the former enabling Internet navigation to find pages with information, exercises and laboratory assignments, the latter providing step-by-step guidance to students in their work.

The d-DcS interfaces with the user through a graphical schematic editor (see Figure 1) and provides a comprehensive library of logic components implementing standard functions. The library includes also user-definable components in the format of Finite State Machines (FSM), developed with the d-FsM. A 8-bit microcomputer component is available in the d-DcS library: the firmware of the microcomputer is programmed at assembly language level, using the d-McE.

To draw the schematic of a circuit the student chooses components from the toolbar, then connects them together using wires. The user can test the network in two different modes: interactive animation and timing diagram. In the simulation interactive mode, the student can "animate" the digital system in the schematic editor, controlling its inputs and observing the outputs. In the timing mode, as in professional simulators, the behaviour of the circuit is shown in a timing diagram window, in which the user can define graphically an input signals sequence and observe the simulation results.

The d-FsM uses the ASM (Algorithmic State Machine) chart (see Figure 2) to graphically define the algorithm of FSM components. The local functional simulation of FSM provides the runtime display of the relations between state and timing evolution. The components defined as FSM can be imported in the d-DcS .

The d-McE is the tool for practicing processor programming and interfacing. The microcomputer component provided includes CPU, ROM and RAM memories, parallel I/O ports, reset circuitry and simple interrupt logic. The custom 8-bit CPU (DMC8) is a simplified version of the well known 'Z80' processor. We have ruled out the possibility of emulating a state-of-the-art processor because we believe that the complex architecture is an obstacle to understanding the basic principles of machine-level programming. The text editor enables users to enter the source code, and a simple command assembles, links and loads it in the emulated system memory.

Programs can be executed step by step in a interactive debugger, where the user can observe, at the same time, the contents present in all the structures involved in the hardware/software system, as register banks, input and output ports, ROM and RAM memories, and the object and assembly code of the loaded program.

In synthesis, the main features of Deeds and, at the same time, the main differences from a professional tool are (a) the educational destination, which translates into an extremely simple user interface and (b) the association with a large repository of learning materials, in the format of original application projects, available on our website [5]. The material covers a digital design course from the foundations to an intermediate level. More details on Deeds can be obtained from [6]. A preliminary work, anticipating the development of the FPGA extension, is contained in [7]. At that time, Deeds allowed the configuration of FPGAs only by exporting, to a FPGA proprietary development tool, the VHDL code of FSMs designed with d-FsM.

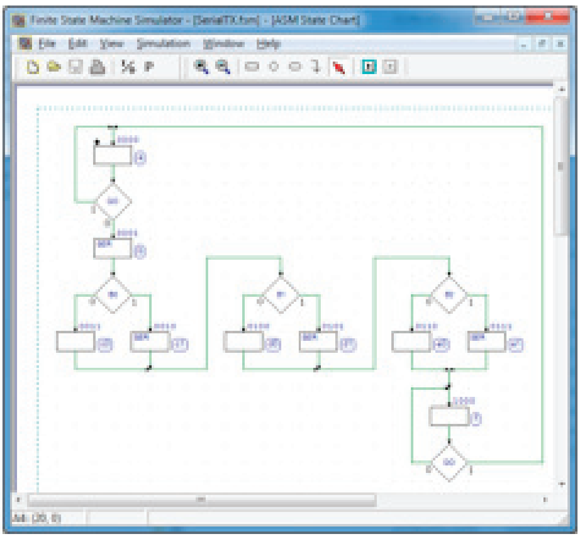

FIGURE 2. *ASM chart of a FSM algorithm described in the d-FsM.*

4 THE "MIDDLE WAY": DEEDS FPGA EXTENSION

Our experience on the field, supported by the data of evaluation questionnaires proposed to a very large number of students, has confirmed the effectiveness of the pedagogical approach based on Deeds. Nevertheless, the issue of introducing the FPGA could not possibly be neglected. Hence, we have searched for an approach able to combine the pedagogical value (and material) of Deeds with the innovation represented by the FPGA. Our purpose is not to simplify FPGA programming via high-level synthesis languages, but to allow a straightforward implementation on FPGA of Deeds projects.

The result is a newly developed feature of Deeds (the FPGA extension), specifically conceived for introducing FPGA-based systems in a first course of digital design supported by Deeds. This extension allows students to export a project into an FPGA chip starting from Deeds, leaving in the background the operations performed by the FPGA-specific EDA tool. It is possible to download, in a FPGA board, a digital system composed of combinational and sequential components, and Finite State Machines (at the time of writing, the inclusion of the DMC8 microcomputer is in an advanced state of development and it will be part of the next release).

It is interesting to notice that learners can interact with the project at two different levels. Beginner users need to be familiar only with Deeds, with no knowledge of HDL and they use the FPGA tools only for the guided, almost automatic, FPGA compilation.

As a result, we achieve the possibility, for the students, to configure an FPGA without necessarily going through the complexity of the full process. It is always possible, for more advanced users, to interact directly with the FPGA tools, with a full control of the design, simulation and compilation steps of the project. Currently the FPGA extension supports a few development boards based on Altera [8] chips. The tool is designed to extend support, from the next major release, also to Xilinx [9] boards.

We are currently running laboratories with students. Next paragraph contains a description of a laboratory session that uses the Deeds FPGA extension.

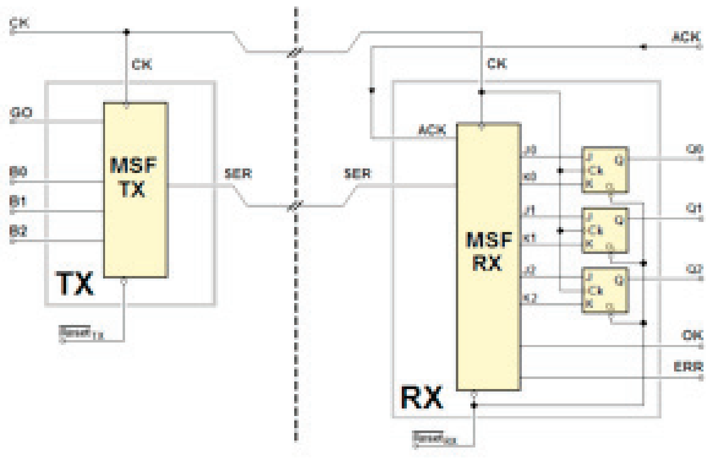

FIGURE 3. *An FPGA Laboratory Session: example of project assignment.*

5 A LABORATORY SESSION WITH FPGA IMPLEMENTATION

In this example, students first design and test with Deeds a basic serial communication system [10]. Then they implement a hardware prototype on an Altera DE2 [8,11] development board. The DE2 board is conceived for the experimentation of digital systems, mainly for educational purposes. It includes several I/O devices and interfaces, from the really simple ones (switches, pushbuttons, LEDs, seven segment displays) to the complex ones, such as parallel and serial interfaces, analog audio inputs and outputs, analog video input and output. The board is based on a FPGA Altera Cyclone® II 2C35, containing more than 30K Logic Elements (LE).

The digital system is proposed to students already partially structured in two parts, that are supposed to be physically separated: a transmitter (TX) driving a serial line and a receiver (RX) decoding it (see Figure 3). The pressure on a button on the TX side generated a serial packet that, after decoding by the RX, will reproduce on its outputs the data set by switches on the TX side.

The student's task is the conception of the algorithms of the two FSM (TX and RX), using Deeds d-FsM and its ASM charts (as seen in Figure 2), followed by their import in the d-DcS, where they fit in the schematic diagram of the complete system, provided by the assignment. The learner must confirm with a timing simulation that the design complies with the specifications.

At this level the procedure for the physical implementation of the project on the FPGA may start. A specialized dialog window allows to associate input and output of the Deeds schematic to the FPGA board devices and resources (see Figure 4). In this example, a clock input (CK) is set up, providing the option to slow down the clock frequency, at run time, to analyze step by step the behaviour of simple circuits.

The FPGA extension generates all the HDL code and project files needed for the FPGA board, and launch the specific proprietary software (Quartus® II, Altera Corporation).

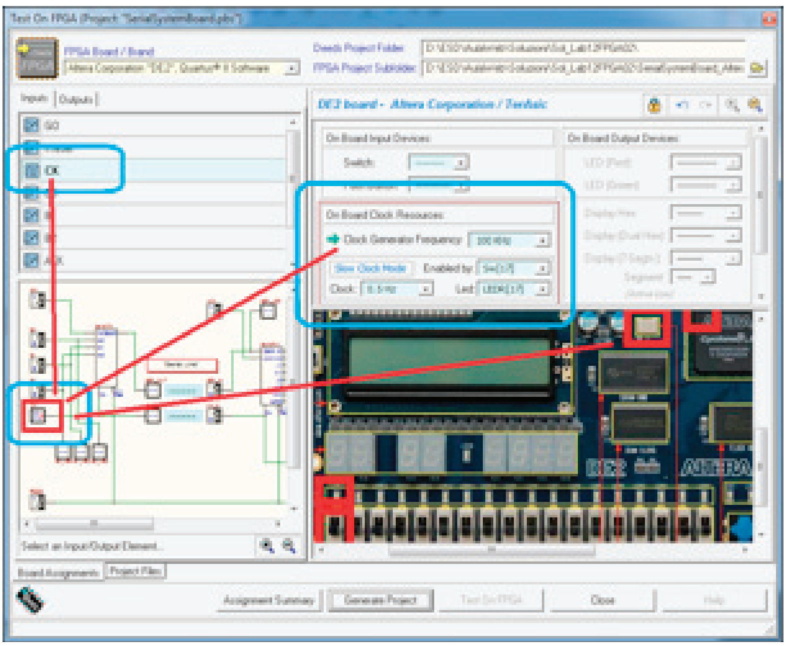

FIGURE 4. *FPGA extension: the associations of inputs and outputs with the board resources.*

Quartus® II is available, as "Web Edition", free of charge for educational applications: we use this tool essentially to compile the project and to transfer it to the FPGA (instructions on how to use the commands for compilation and programming are provided). After the downloading of the FPGA configuration file it is possible to proceed to the physical testing of the project. Figure 5 shows the mapping on the board of inputs and outputs suggested by the project assignment. By using buttons and switches and observing the status of the LEDs it is straight forward to check the correct behaviour of the design.

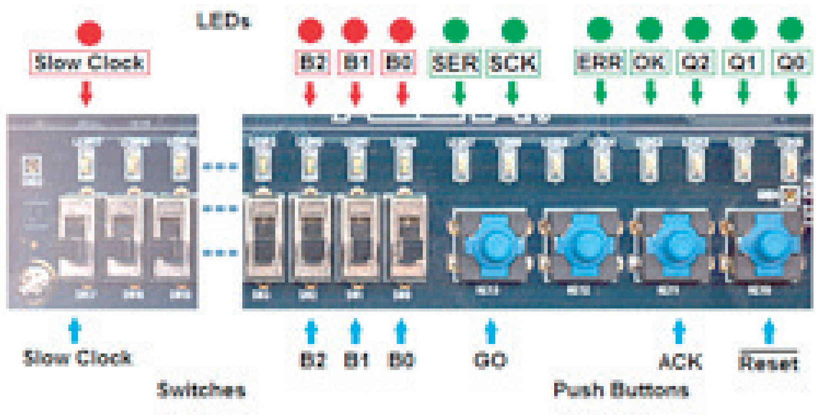

FIGURE 5. *Board input and output resources used for testing the project.*

6 CONCLUSION

We set up 25 test sites, each one of them equipped with a PC and a DE2 board. Approximately 250 students of our introductory courses of digital design, assembled in groups of two, have participated to the first two labs developed with the Deeds FPGA extension.

We can draw a few preliminary conclusions from our careful observation of the student activity. First of all, the technical aspect of the labs was almost flawless. The Deeds extension worked smoothly: there were no problems with the compilation of the files and the operation of the DE2 boards. The instructions guiding the experiments [10] proved to be exhaustive and easy to understand. Students learned very quickly the operating procedures and were able to perform successfully the experiments.

The most significant result of the labs was, from our point of view, the very positive level of acceptance by students. The number of lab attendees has increased noticeably and their interest has definitely been stronger than with the existing simulation labs. It looked like they were aware of the importance of the issue and of its significance for their formation. Undoubtedly, the success of the experiment went beyond our own expectations and did encourage us to proceed further in that direction. It is not easy, in this phase, thought, to provide a reliable quantitative evaluation of the effectiveness of the FPGA extension.

Deeds FPGA extension ensures continuity between the classic, schematic entry based education in digital design and the new approach with HDL and FPGA. It allows us to continue to use a large amount of learning materials, developed over the years and still technically and pedagogically valid, re-targeting it toward FPGA.

A laboratory equipped with PCs and FPGA boards, Deeds and Quartus® II is very flexible. It may serve, at the same time, the needs of introductory and intermediate courses. Students have the possibility of choosing the level they wish to interact with the project: they can start from Deeds schematics, then switch to the HDL level and, finally, take advantage of the powerful features of the professional tool, such as RTL view, placing and routing, etc.

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239 DIDACTIC KIT FOR THE STUDY OF CAN BUS

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ABSTRACT

This project aims to create a development kit to help engineering undergraduate students to explore the CAN (Controller Area Network) bus applied to vehicular control. This protocol has restricted access, generally used by carmakers, and our goal is to present a message transmission and reception simulation on an electronic kit, in order to show the reliability of the system. The CAN bus could replace most of the wires inside the vehicle, allowing flexible management of car electronic modules.

Keywords: vehicular control, CAN bus, embedded electronics.

1 INTRODUCTION

Over the last two decades, microcontrollers have become considerably inexpensive, and as a result they are very common in vehicular embedded electronic systems [1]. Embedded electronics, both from software and hardware, have been growing steadily at a rate of about 10% per year.

The automotive industry is currently the world sixth largest economic sector, with around 70 million cars built per year. Several improvements have been incorporated in that industry, in order to provide better performance, safety, comfort, and convenience, most of those improvements involved embedded electronics. Nowadays, there are many cars that have as much as 70 microcontrollers, with a memory of up to 500 MB. All those devices are connected to automotive communication network as a Controller Area Network (CAN), which controls all the car electronics. The messages' broadcast among vehicles is now explored by carmakers in some countries to acquire road data and even for communication between vehicles. [2]

2 CAN BUS

Due to its performance and versatility, the CAN bus became a standard system for vehicular applications. The automotive control units are connected to networks through a data bus, reducing the amount of the electrical cables, and consequently the failure probability of the devices connected to network. [3]

The CAN is based on the multi-master concept, namely, many electronic control units are interconnected through a linear structure of the bus. One of advantages of this type of topology is that if there is a failure on a single module, that failure does not allow the access to other modules in the network. This would not happen in a star topology, in which one single failure can lead to a global failure of the full system. [3]

Each message of the CAN is labeled by one identifier (ID) that represents its information (e.g. ID 00001100000 could be the identifier of the engine rotation.), or better, it uses an addressing of the message. [3] The identifier of the automotive system is not universal, furthermore each carmaker is responsible for allocating the IDs in their projects, although this information is kept confidential.

Besides, the ID defines the message content and is also responsible for its priority when the data is sent. An identifier with a low level binary number gets higher priority while an identifier with a high level binary number gets a lower priority. [3] (e.g. the ID 00000100000 is a 0x20 hexadecimal, it gets a higher priority than an ID 00000110000 which is a 0x30 hexadecimal.)

The CAN Bus is developed in two logic states, that are recessive bits (logic level 1) or dominant bits (logic level 0), the dominant bit overwrite the recessive one when they are sent at the same time. Figure 1 shows an example when more than one message is sent at the same time. [3]

Nodes at Network	ID												
A	205	0	0	1	0	0	0	0	0	0	1	0	1
B	250	0	0	1	0	0	1	0	1	0	0	0	0
C	400	0	1	0	0	0	0	0	0	0	0	0	0
Win Bus	205	0	0	1	0	0	0	0	0	0	1	0	1

FIGURE 1. *Prioritization of messages on the CAN bus.*

When the CAN bus is free, the node inside of the network can send its message at any time. However, if many nodes send their messages simultaneously, the ID with the highest priority will control the bus [3], according to figure 1. When a transceiver loses its arbitration, it automatically switches to receptor mode and repeats the attempt of transmission when the bus is free.

There are two different formats for the CAN frames, the CAN standard or CAN 2.0A and CAN extended or CAN 2.0B, shown in figures 2(a) and 2(b), respectively

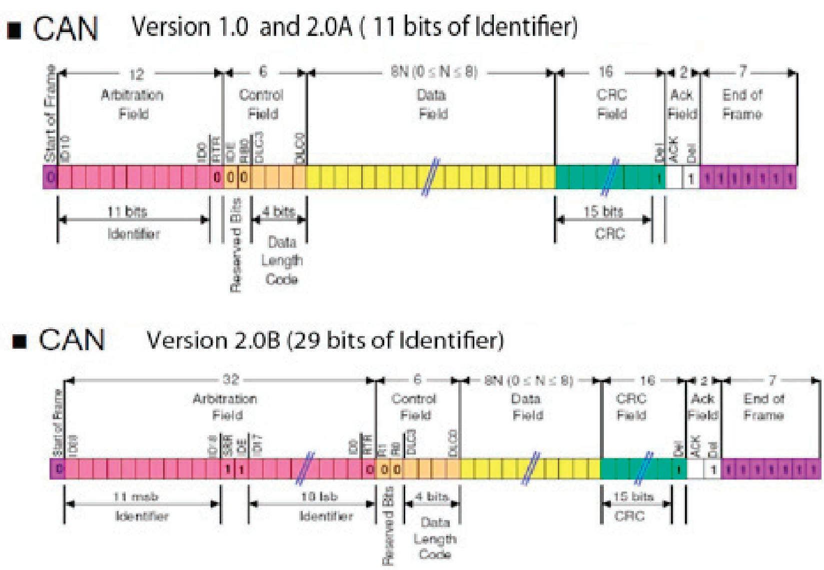

FIGURE 2. *Frames of (a) CAN 2.0A (11 bits ID) and (b) CAN 2.0B (29 bits ID).*

The main difference between those two formats is the number of bits in the Identifier (ID). Each field of the CAN data frame can be described as:

Start of Bit (SOF) - It is a dominant bit. It begins the message and it synchronizes all the nodes. [7]

Arbitration Field - The Message Identifier Field can have 11 bits (CAN 2.0A) or 29 bits (CAN 2.0B), and some additional control bits. For the transmission in this Field, the sender checks each bit in order to analyze if it gets priority or if another node has higher priority in sending messages. [3]

Control field – Bits to control the size of the data message.

Data Field - This Field determines the amount of bytes which the message will send.[4]

CRC (Cyclic Redundancy Check) Field - It has a number sequence used to check the errors on the frame.

ACK Field - It contains signal of acknowledgment and check if the message was received without errors.

End of Frame - This Field shows the final message and it sends 7 recessive bits.

The length of time segments Sync_Seg, Phase_Seg1 and Phase_Seg2 are defined and programmed in units of time quanta. A time quanta is the unit of time derived from the oscillator frequency divided by the CAN controller's programmable prescaler, which ranges from 1 to 32. The original time (1/frequency) of the oscillator is defined as the minimum time quanta. Figure 3 describes the division of one bit.

Synchronism	Propagation	Phase1	Phase2

FIGURE 3. *Division of 1 (one) bit [4].*

According to Voss, these segments are defined as [7]:

SYNCHRONIZATION SEGMENT: The Synchronization Segment (SyncSeg) is the first segment and it is used to synchronize the nodes on the bus. Bit edges are expected to occur within the SyncSeg. This segment is fixed at 1TQ.

PROPAGATION SEGMENT: The Propagation Segment (PropSeg) exists to compensate for physical delays between nodes. The propagation delay is defined as twice the sum of the signal propagation time on the bus line, including the delays associated with the bus driver. The PropSeg is programmable from 1 to 8TQ.

PHASE SEGMENT 1 AND PHASE SEGMENT 2: The two phase segments, PS1 and PS2 are used to compensate for edge phase errors on the bus. PS1 can be lengthened or PS2 can be shortened by resynchronization. PS1 is programmable from 1 to 8TQ and PS2 is programmable from 2 to 8TQ.

3 PURPOSE AND METHODOLOGY

The CAN bus is a very useful protocol in the automotive, naval, aeronautic, and medical industries. Since the content of CAN Bus is not easily found in textbooks, this article intends to explore its conceptualization. We explore its functionalities and performance using a simple procedure to manage CAN bus, in order to allow future researches with new embedded electronic devices. The major goal here is to introduce a simple network of CAN communication, a didactic kit, using three nodes connected to its bus.

Using this didactic kit, students can learn through the development and implementation of software on the PIC microcontroller and CAN controller. Additionally, an application on top of this kit, using automotive power locks triggered by the CAN bus, was developed.

The didactic kit has three nodes that are already connected among themselves, in order to allow communication through the CAN bus. Each node has a microcontroller (PIC 16F877A), a controller CAN (MCP2515), a display LCD (16X2), inputs and outputs (I/O). The main program is introduced in the PIC microcontroller, where it will control the node.

We have created an identifier to each node, connected to the network, and defined a priority degree. For each node connected to the network, a working condition was defined, in which the node sends a message to CAN bus.

The transmitter board sends a message with the identifier number to the bus. The receiver board shows the status information of the node in a display as soon as it receives the message and activates some actuator. Here, the actuators were represented by an engine and some LED´s.

An electrical lock, incorporated for safety reasons, is used to simulate the CAN application. According to the message received, the receiver board gets this message and shows it on a display. Moreover, the LED is turned on in order to indicate which message was gotten by the receiver board such that it activates a power circuit of the electrical lock engine.

4 DEVELOPMENT

There are several procedures that students need to do in order to learn the communication.

- Create a basic software to activate a communication between two modules.
- Set one module as a transmitter and another one as a receiver.
- Set one message ID 0x60 hex to send the data to the receiver.
- The module will read a switch input state where High state is 1 that it will be sent as 00000001, else is sent 00000000.
- The receiver will be programmed to read the message ID 0x60 and verify the data content, if it is 0000001 the receiver will activate the output (e0) (LED On), while if it is 00000000, the output (e0) is to deactivate (LED Off).
- Finally, the student has the know-how to send and receive how much message they need and the theory of CAN Bus will be understandable. The figure 4 shows the node one sending a message to node 3. The red LED´s in both nodes are turning on because messages are being transmitted. It is clear that student will understand the CAN BUS after he makes the kit works.

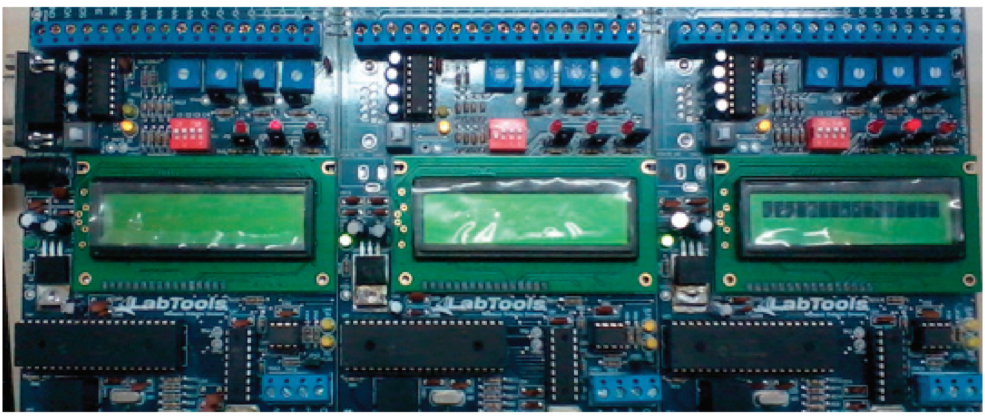

FIGURE 4. *CAN Board.*

The data transmission rate was set to 1MHz like the figure 5 bellow, and we assigned the ID 0x60 to node 1 and ID 0x65 to node 2. In order to set every register of CAN controller, we used the write and read functions as SPI protocol (Serial Peripheral Interface). Then, we started setting the registers to activate the CAN bus, and after that we set the transmission and reception registers, defining the IDs that were received, the message size and the format CAN 2.0 A (11 bits). [5]

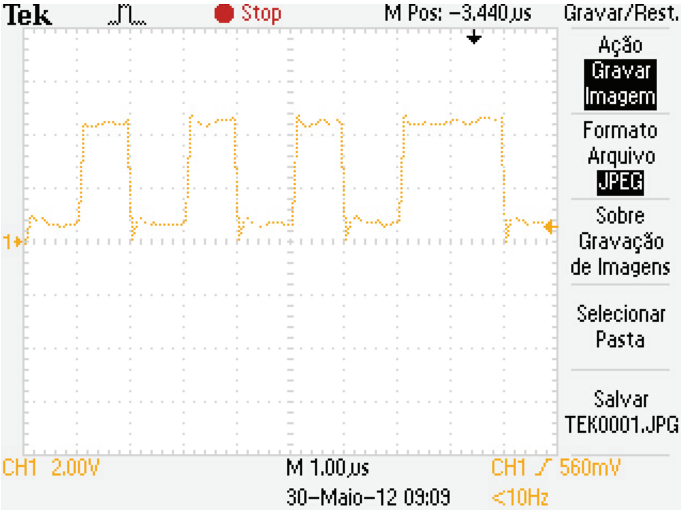

FIGURE 5. *Transmission Rate.*

In order to set the synchronism and the transmission speed in the network, we performed the division of bit according to the transmission rate, leading to the time value of 1 bit equals a 1μs (one micro second):

Time of 1 bit = [1/Tx. Transmission (1MHz)] = 1μs.

The team developed a calculation sheet using the software Microsoft Excel, building an algorithm that takes into account all the possible numbers of tqs for the transmission rate of 1MHz, according to the following equation:

TQ= [2*(BRF+1)]/20M [5]

According to simulation results, we found the value of BRF (internal pre-scale of board's oscillator, in this case is 20 MHz) equal zero. Using BRF equal zero, we found the time of 1 TQ equal 0.1μs. Considering the tq's number, we established:

Number of TQs = (time of 1 bit/ time of 1 tq) = 10 tqs.

Finally, our group found the number of 10 tqs that mean we have 10 subdivisions in our bit to be sent. We considered the division of tqs in bit of the following way, according to figure 6:

Synchronism	Propagation	Phase1	Phase2
1 TQ	3 TQS	3 TQS	3 TQS

FIGURE 6. *Division of Tqs in bit.*

After configuration of all the registers and of network synchronism and speed to operate with a transmission rate of 1 MHz, we created a transmission and reception function using a software. Using that software, it was possible to determine the strategy of working of all bus linked modules.

We have used an analogical channel of the microcontroller to manage the signal that will be converted through an A/D channel converter [6]. In addition, we have used a protoboard in which the LEDs were connected.

5 CONCLUSION

Nowadays, carmaker industries preserve their know-how on the CAN Network. Therefore, students who are enrolled in engineering courses have essentially no access to such information, due the lack of specific literature. The focus of this didactic kit is to help students to learn, step by step, on embedded electronics and their control. First of all, the student will learn about the whole hardware kit, in which they will understand how the CAN controller works. At that point, they will develop the software to test the circuit. After testing the system, it is necessary to configure the transmitter and receiver registers, as well as to create their filters, such that the messages can run correctly, finally the student will control the vehicular electrical lock. This allows the students to learn on the whole hardware system, all data controller CAN and how to have control to send and receive messages on bus.

6 ACKNOWLEDGEMENTS

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240 INITIATIVES TO PROMOTE SCIENCE & TECHNOLOGY CAREERS AND THEIR IMPACT ON IT'S SECTOR AND ON DEVELOPING COUNTRIES

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ABSTRACT

Science and Technology are doubtless important in today's world and assume a key role concerning its economic aspects. Despite that, courses with those subjects are occasionally not even considered by teenagers as future careers. Regarding this, a United States Government initiative, STEM (Science, Technology, Engineering, Math), established in 2006, promotes to students these courses. In this concern, this research shows which fraction of students choose S&T as careers since there is a very high demand on labour markets and what an initiative like STEM can do for developing economies like China and Brazil where the markets are always in need for professionals in these careers. An analysis of current data available showed that S&T promoting programs has succeeded and could be applied to developing countries, which would encourage the area's growth. Also, each place has its own culture and peculiarities, which requires the creation of a singular promoting program that correlates with each region. Furthermore, this analysis proposes to evaluate in which way a larger number of skilled professionals in this areas could make the Information Technology (IT) grow in the economical and laboured environments since it is very important to the market's development.

Keywords: Engineering, Initiatives, Information Technology, career, China, Brazil.

1 INTRODUCTION

1.1 Information Technology History

Information technology (IT) concern hardware and software to manage data and this employment's importance have been rising through the years in markets like logistics, business, engineering and others also because the attendant rise in using electronics, computers and telecommunications [1]. This digital information's modern science growth was largely influenced by industrialization period and also by the launch of the first computers with integrated circuits in 1997 (Apple II) and 1981 (IBM).

Information Technology focus on networks of computers and how they can best contribute to the business, logistics and other markets activities. Utilizing networks, IT promotes a shared database that facilitates for firms to refresh its records without having to share it each time some change is done. Software that makes this database ready for use has become a billion-dollar industry [2].

Regarding the high importance of IT in several markets it is of vital importance that IT careers and positions has to be widely disseminated because it will improve market's qualities and also will promote a growth in professional's number working in this area.

1.2 IT IN COUNTRIES AND SOCIETY

Internet and its functions are examples of IT in daily functions. In December 2003 fully 63 percent of adult Americans and three-quarters of those aged 12-17 reported using the Internet. [4] Considering colleges, for example, there is a little amount of classes that actually use some computer-based resources for teaching. The available data to a large degree support their contentions regarding the use of IT within academe. The Green study, for example, reported relatively low use of computer-based classrooms/labs (32.1 percent of classes), course management tools for online course resources (33.6 percent), and Web pages for class materials (37.4 percent of classes). With an average of 82 percent of campuses providing access to a CMS, this suggests a tremendous underutilization of an expensive campus investment. More encouraging signs include the incorporation of e-mail (in 71.8 percent of classes) and Internet resources (in 52.9 percent of classes). [5]

Despite the importance of IT and its use in society's life, people specialized in this matter are still missing. It is possible noticing the IT's considerable growth in several countries. India is the country that holds the biggest investment on IT global market in an offshore competitive scenario, USP 100 billion, approximately. Other countries like Brazil and China spend almost USD 80 billion. [6]

2 DATA AND ANALYSIS

Regarding the analysis of S&T in the countries, the rate of graduates in engineering in countries, for example, is a good parameter of how much it will have professionals who can potentially work in IT. There is no direct correlation between the graph below and the global IT-BPO market, but certainly the investment on S&T courses is essential to have professionals to fulfill market's needs. On the graph below it is possible to note that the growth of engineers is very different among countries, which somehow explains the economic growth of each country. [7]

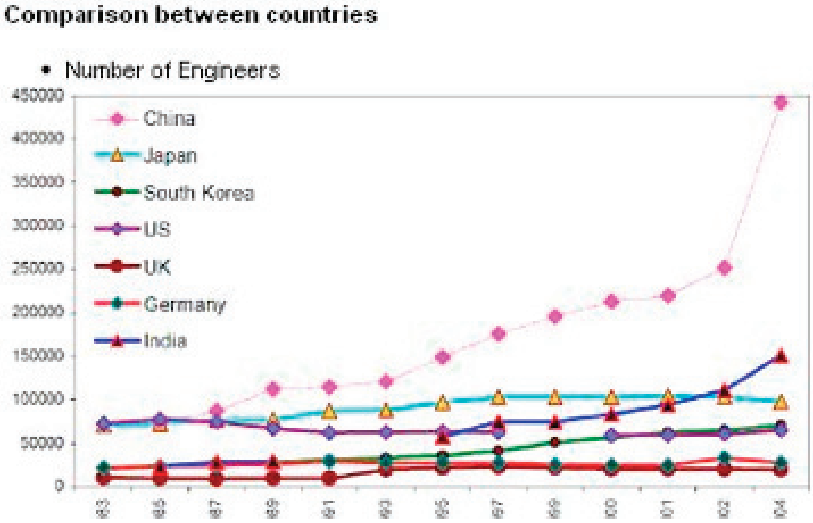

FIGURE 1. *Number of Engineers per year in each country.*

This scenario reflects the amount of students graduated in engineering. In the year 2007, for example, the percentage of engineering graduates over the total graduates in Brazil was only 5.0% if compared to China that achieved 35.6% [8].

In Brazil, for instance, the rate of engineering graduates is lower than compared to other countries. It is occurring an increase of engineering courses, but that haven not reflected yet in the raising percentage of students in those courses. The private education, that achieved almost 2000 courses in 2010, is growing faster than the public total of engineering courses, 1000 courses approximately in the same year, even though bough are increasing. [9] This conflicts with IT's impact on the country once IT corresponds to a percentage of Brazilian GDP. In 2008, the total expenses with IT's market, that includes expenses with IT, Business Process Outsourcing (BPO), exports, communications and IT in-house, was USD 139.1 billion. Concerning hardware, software and IT services, the highest expense was the hardware category with USD 16.2 billion. [6]

In the United States Of America (USA), it is possible to notice that the growth of students in engineering is low, but still superior to Brazil's. It should be noted that in the USA there was an overall growth of the other graduation courses. While the total number of graduated students grew 72% from 1980 to 2009, the number of graduated in engineering increased by only 22%. When it is analyzed from 1990 to now, the situation is even more aggravating, because while the total number of graduates increased by 52%, in engineering the growth was just 2.5% having also negatives growths over the period. The number of students enrolled in colleges is not increasing much, which also means that the number of graduates also will not increase in the short term. [10] The graph below shows the number of formed over the years in total and in Engineering. [9]

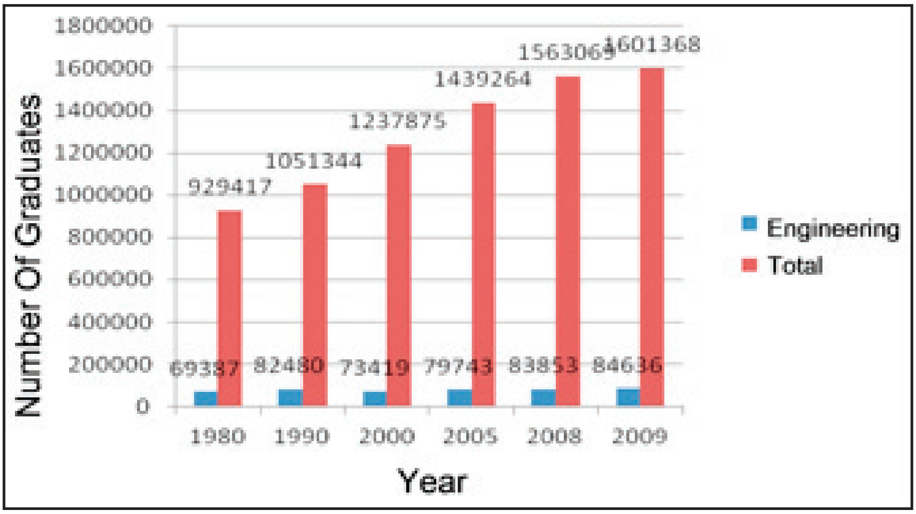

FIGURE 2. *Number of Graduated in Engineer per year comparing to graduates of all courses in USA.*

This lack of interest should not be set on lack of good opportunities in the area since the wages are 25% bigger than in the other areas and has an unemployment rate of only 5.5%. Furthermore, the demand of professionals is large. The USA graduates 86000 engineers a year and companies like Cisco and Silver Lake Partners need to hire 110000 engineers together. [11]

These indices are quite different when considering China which has formed in general. In 1998, the number of graduates was less than one million. In 2010, was 6 million. The enrollment in 2011 is five times higher than in 1990. China graduates ten times more engineers than USA (860000 professionals). In China, 63% of the students (1.8 million) made enrollments in S&T courses in 2009. [12] The situation in China is so outstanding that 1.27 million Chinese students are studying abroad. For example, 26% of foreign students in Australia are Chinese. The interesting is that much of them return to their original country. In 2010, 284 thousand were studying abroad and 126 thousand returned to work in China. [13]

Beyond all this impressive numbers it is possible to note that the research developed in China has presented a global significance in the recent years. The amount of publications has increased significantly, but the number of citations is far inferior to the other countries. China increased more than seven times their published papers. In 1996, USA has published 292.513 scientific papers and China only 25.474. However, in 2008, USA produced 316.317 while China did 184.080. [14]

Despite this growth, China is facing problems with regarding the difficulty of forming professionals that in the end of the course have knowledge of current technologies, which change all the time. China has weak experimental conditions: there are few school-companies partnerships, which make students have less chance to learn in practice. [15]

Another country that has made significant progress is India. According to the table below it is able to see that there was an increase of graduates in engineering and a leap in computing and IT. [16]

Table 1. Number of students in engineering courses in India divided by type of engineering

2.1 INITIATIVES TO ENHANCE S&T

With all this problems and the lack of professionals in S&T careers, initiatives and campaigns must be done to promote them. Each country have acted in a different way, since it appears that the reason for a few practitioners are different.

Brazil today has a growing number of undergraduate places and has a leap of 4% to 5.1% of GDP investment in education between 2000 and 2010 having initiatives such as:

a) Opening and encouraging the opening of new courses and Universities
b) Encouragement of science and scientific exchange
c) Opening of new technology and technical courses throughout the country
d) Encouragement by public agencies

In Brazil, in particular, The Mechatronics Engineering Department of Polytechnic School Of University Of Sao Paulo has a project for undergraduate students named Tutorial Education Program for Mechatronics Engineering. The students that participate of this program developed a program called Advanced School of Mechatronics Engineering (EAEM) during a week for students that have just graduate from high school and technical courses. In this program they attend classes of calculus, robotics and other courses that take part in the engineering graduation program and also develop a project that will use the newly acquired knowledge. This program facilitates early contact with the S&T academic and working worlds and also provides contact with students that are currently enrolled at S&T graduation courses. [17]

In USA, President Obama launched in the USA in November 2009 the “Educate to Innovate” campaign for excellence in science, Technology, Engineering and Math (STEM) education. Speaking to key leaders of the STEM community and local students, he announced a series of high-powered partnerships involving leading companies, foundations, non-profits, and science and engineering societies dedicated to motivating and inspiring young people in S&T. The commitments, valued together at over $260 million in financial and in-kind support, will apply new and creative methods of generating and maintaining student interest and enthusiasm in S&T, reinvigorating the pipeline of ingenuity and innovation essential to this area’s careers. This identifies three overarching priorities for STEM education: increasing literacy so all students can think critically in S&T; improving the quality of math and science teaching so American students are no longer outperformed by those in other nations; and expanding STEM education and career opportunities. [18]

China presents the higher numbers of people graduated in engineering. Some initiatives are:

a) 985 project
b) Investment in P&D: 2% of Chinese GDP (US$146 billion) em 2010. From 2000 to 2004 the average increase of annual investment was US$1.5 billion. In 2009, the education expenses were US$213 billion, increase of 329% in comparison to 2000.
c) Internationalization of graduation with partnership with other major universities

In particular, the Project 985 was made in 1998 to develop a small group of highly competitive institutions. Some received about 30 billion yuans in funding in 1998 alone, and such groups can have half of his own income from trading and private funds. The investment in P&D is a key component of the reform in education. The projected investment for 2010 was 2% of Chinese GDP in the sector (US$146 billion), and from 2000 to 2004, the average increase in annual investment in research was US$1.5 billion. These measures took many Chinese universities of the abyss. [13] [16]

In India the increase in vacancies was started in the '50s, with the establishment of a development plan for higher education in the country. With this plan the number of schools of general character, professional education and universities increased by about 10 times in 50 years. [7]

The financing of higher education in India was also crucial for growth in the number of places in higher education. The financing took the elitist character and limited in higher education, going to a democratic character, with almost one third of the students belonging to lower strata of society.

It is possible also cite other initiatives taken by the government to facilitate access to higher education:

a) Central Universities with high quality of infrastructure for teaching and research
b) Institutes recognized internationally for its courses
c) Openness to the professional education sector to private capital on a large scale
d) Openness of a campus of a university in other cities

Initiatives and promoting programs are of major importance in order to enhance S&T. To apply them, an analysis has to consider the data below for acquire the knowledge of, for example, which portion of the country's population chooses S&T careers and how many courses of IT and S&T are available.

3 CONCLUSION

Concerning the importance that IT and Science and Technology careers as explained at the introduction and the impact that the analyzed countries have in the world as a raising economy and country, it is of the highest importance that initiatives like STEM, FLL and EAEM take place in this country so then more people and students will be interested on taking S&T courses as careers.

Regarding this, it would be good and appropriate to these countries that promoting initiatives are amplified and increased. Knowing all the social and political conditions, lectures at high schools explaining and exposing S&T careers would increase interest and curiosity for these areas and also would take away the common doubt of which course to do as a graduation. Programs like EAEM would also enhance the interest in S&Ts because it possibilites earlier contact with graduation matters and also promotes knowledge about the area.

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241 INFORMATION TECHNOLOGY IN THE COMPUTER ENGINEERING CURRICULUM: AN ANALYSIS AMONG UNDERGRADUATE INSTITUTIONS

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ABSTRACT

The Information Technology (IT) development was responsible for many services without which it is not possible to imagine the modern society. In summary, this analysis suggests that computer-engineering schools over the world differ with regard to the number of undergraduate disciplines in which IT topics are addressed. With this in mind this article seeks to understand the importance of the under graduation, in particular the computer engineering courses, to the development of the IT field. In this sense, the current paper presents how inserted is IT in these courses by comparing the workload dedicated to this field of knowledge. The data was collected in the official curriculum of the best university of each BRICS member and the top undergraduate institutions. Furthermore, the supply of skilled IT professionals is heavily conditioned by those differences. As a matter of that fact and concerning its economic impact it is highly recommended to enhance and promote the people's IT interests in some ways like establishing extracurricular courses that regard IT knowledge.

Keywords: Computer Engineering, Curriculum comparison, Information Technology.

1 INTRODUCTION

The Information Technology development, during the dot-com boom in the 1990s, raised high expectations about its future and importance to the following generations. Despite of the bust of the speculative bubble it is undeniable the crucial role in the progress of many fields as medical, environmental protection, telecommunications.

Even though those environmental and social importance the "productivity paradox" [1]-[2] emphasized that regarding the global market, Information Technology itself, was not responsible to an increase of productivity. Even so companies and governmental investments, related to IT, have never feared this prospective, which resulted a huge growth in this market share over the years. Several theories have been used trying to explain this paradox as "Strategic Necessity Hypothesis" [3]-[4], "The Nolan Cycle" [5]-[6], the explanation about these theories is out of the scope of this current article.

In face of these IT has grown. In 2002 almost 50% of U.S business investments were in IT [7]. In 2007 Brazilian e-commerce sector grew 45% (E-BIT) what represented US$ 3.5 billion in transactions while its GDP did not grow more than 5% [8] At this same period China had become the largest IT market in Asia/Pacific reaching US$217 billion with a 5.9% growth rate [9].

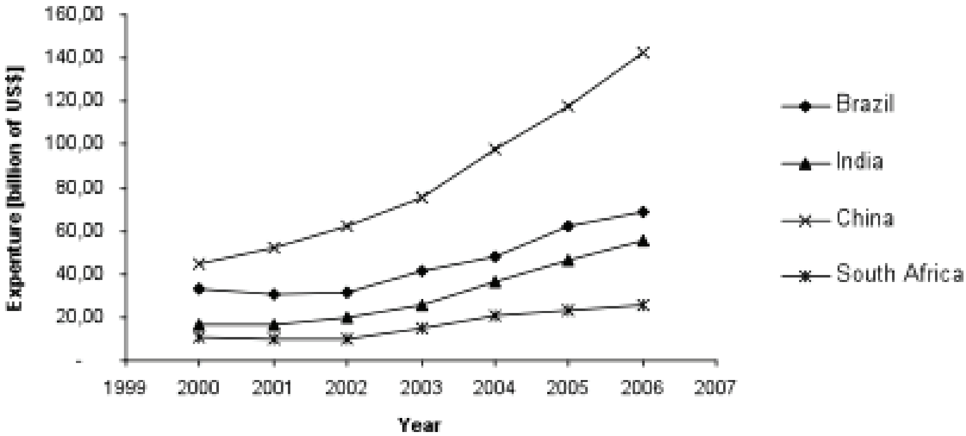

FIGURE 1. *Information and communication technology expenditure.*

In accordance to this growth, the labour market has demanded a huge number of skilled professionals. The main question is how do different economies face this growing demand? The key to understand this problem may lay down at a microanalysis at the basis of this entire process, in other words it might be necessary to analyse how the universities insert IT into their undergraduate computer engineering courses.

2 METHODOLOGY

According to [10] the information sharing process is divided in two parts: the Information Technology (IT) which is concerned with the technical aspects and the Information System (IS) which deals with the information itself and the working flow. Despite that some authors defend the thesis that the IT concept includes both, technical and operational aspects [11]. This article is aligned with the second definition.

Only Computer engineering courses was analysed to the detriment of other careers as Computer Science or Software Engineering. To this article computer engineering is a discipline that embodies the science and technology of design, construction, implementation, and maintenance of software and hardware components of modern computing systems and computer-controlled equipment [12].

With that in mind this paper has consulted the online undergraduate curriculum of the computer engineering course from the best university [13] of each BRICS' member (i.e. Brazil, Russia, India, China and South Africa) in order to draw a comparison among these courses and the world's best ones regarding the workload of IT disciplines in them programme structure.

The criterion here used to determine the presence of IT in the subjects was: if it's found any of the following IT topics in the discipline's name: Software Engineering; Data bases; Artificial Intelligence; Graphical computing; Computer Networks and Multicore Systems; Telecommunications; Signal, Control and Process.

On the other hand to classify the subject as basic or technical, the parameter used was USP's computer engineering course, which was the freshman and the second years as it's basic cycle. The following keywords were used: Calculus; Linear algebra; Physics; Computing Instruction to Engineering; Engineering Drawing; Chemistry; Numerical Methods; Engineering Mechanics; Introduction to Material Science; Electrical and Electronics circuits; Introduction to Digital Systems; Energy, Environment and Sustainability.

It's necessary to emphasize that if a university better positioned in the ranking did not offer the Computer Engineering course until the moment this article was wrote the following best placed institution will be used in the analysis. In case that it was not possible to find a course which matches the requirements, among the three best universities of a specific country, the current country won't be included in this paper.

3 DATA

Concerning the previous criteria it was built the Table 1, which points out the universities who matched the requirements and whose courses this paper will analyse. It's important to consider the difference among the course structure, such as programme length, number of credits and the workload.

Ranking	University	Country	Score
1	Massachusetts Institute of Technology (MIT)	USA	100
8	ETH Zurich	Switzerland	58,6
9	National University of Singapore (NUS)	Singapore	57
22	The Hong Kong University of Science and Technology (HKUST)	Hong Kong	43,3
49	Indian Institute of Technology Bombay (IITB)	India	31,8
97	University of Sao Paulo (USP)	Brazil	22,9
227	University of Cape Town (UCT)	South Africa	13,6

These aspects are vital to build a well-balanced analysis, they may be found in Table 2, the blank fields correspond to information that could not be found.

University	Course Length	Workload [hours]	Total Credits
MIT	4 Years	3192	228
ETH Zurich	4 Years	-	300
NUS	4 Years	5200	124
HKUST	3 Years	-	105
IITB	4 Years	-	252
USP	5 Years	4410	275
UCT	4 Years	5200	520

The chart contained in Figure 2 concerns the comparison among the percentage of credits units, dedicated to basic and technical disciplines.

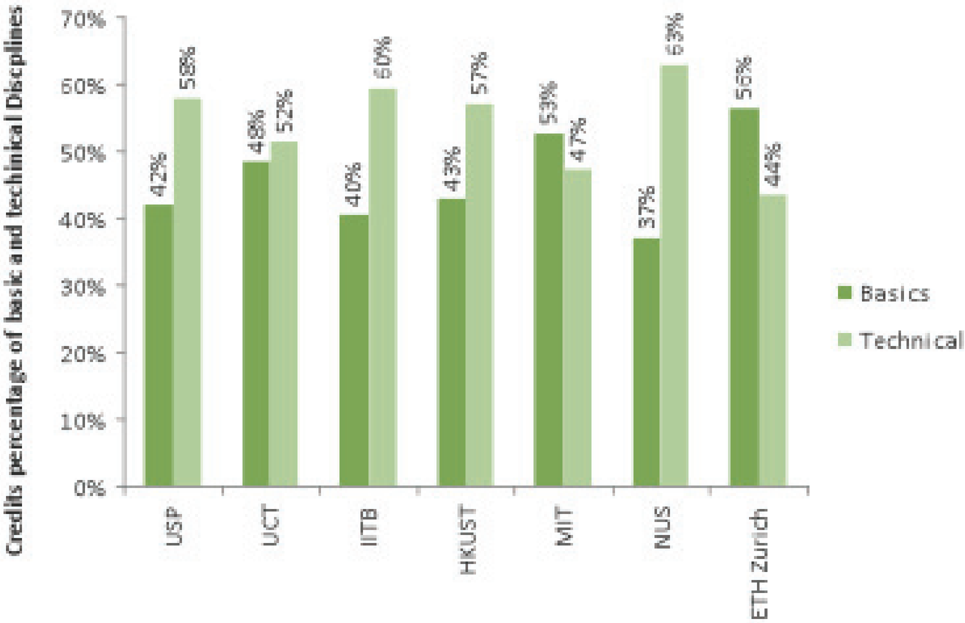

FIGURE 2. *Basic and technical disciplines in each programme*

Despite of the fact that credits unities varies according to the university, once this article want to analyse the importance institutions give to IT in their curriculum, it was decided not to include the workload in hours, as a weight in this analysis, because it could put three years length courses in disadvantage.

The Figure 3 is divided in two parts; the first four columns refer to the BRICS universities analysed while the following three concern the top universities. Two average lines were draw to facilitate the comparison.

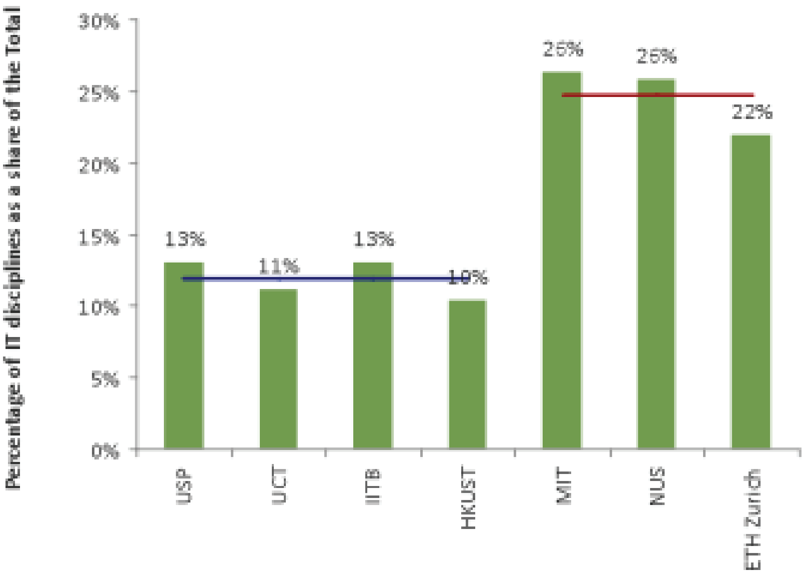

FIGURE 3. *IT disciplines in each course.*

4 ANALYSIS

During the research to write this papers it was noticed some particularities of each institutions that might make possible to explain the contrast among the first group (BRICS member) and the second one (top universities) regarding the workload of IT in their curriculum structure.

The difference concerns the ideal of skills an engineering should have, an example of that is the Health and Lifestyle discipline at HKUST's programme or USP's Laws Institutions. Disciplines as the mentioned before are part of the obligatory ones and despite the fact they beyond the scope of an engineering skill it elucitades the institution philosofy.

It is also possible to notice that univerties that prioritize a wider knwoledge on computer engineering (i.e its programme has a rigid structure covering a bit of all fields of computing knowlegde, without a specific enfasis) as USP, UCT, IITB and HKUST tend to have a smaller workload of IT in their programme, then the other institutions which have inside the computer engineering course enphasis as networks or IT.

5 CONCLUSION

For all the reasons presented and due to IT's vital importance to the modern society it is crucial to the universities being aligned with the new technology tendency in order to be capable of fulfilling the demand of skilled professional. The data collected has shown that in all of the top BRICS universities the percentage of IT disciplines is bellow of the top institutions, and it is important to improve this deficiency. The main solution this article proposes is to make under graduation courses more flexible allowing students to choose their specialization during his engineering formation.

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244 SELECTION OF APPROPRIATE PROGRAMMING LANGUAGES FOR ENGINEERING APPLICATIONS

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ABSTRACT

When students enter the University from High School they are usually familiar with at least one Application Program / Programming Language. This is usually Microsoft Excel. It therefore is very appropriate to use that language for First Semester applications and expand the basic knowledge that students have with numerous solutions in all areas of Engineering, Statistics and Mathematics.

To give students greater flexibility and more programming ability, languages like MatLab and C++ are considered in the second semester. Both of these languages have capabilities to solve some of the most intricate Engineering Problems. It will be shown that MatLab is far superior in all Engineering applications and can solve problems with very simple and short programming commands. Especially in Electrical Engineering, solutions for complex mesh and nodal problems can be accomplished with a few keystrokes. Providing students with MatLab capability in Engineering lecture rooms or letting them use laptops with MatLab installations will provide quick solutions to many problems that were quite difficult for students to solve with their calculators.

Keywords: Programming Language, Microsoft Excel, MatLab, C++, Electrical Engineering

1 INTRODUCTION

As Students enter the University of Pittsburgh at Bradford in the Fall semester, they will take their first Engineering related course, which is “Introduction to Engineering Analysis” or simply referred to as Engineering 11. This course deals with many different areas of Engineering and gives the students insight into how to solve and how to approach these problems. Statistics, Energy and Engineering Economics problems round out the course The spreadsheet application program of Microsoft Excel was chosen because many students were somewhat familiar with it from High School, and some students were very good at it. Right from the beginning of the course, students were put into teams and to make sure that the ones that did not have Excel experience, that they were teamed with the ones that did. Usually the inexperienced students picked the basics of the program up very quickly with the help of their teammates and may be one or two extra sessions with the Professor. All sessions of the course were held in computer labs which have some of the most up to date equipment for each workstation and for teaching. Since so much of the solution to problems was done with Excel, the course required two textbooks, with the second one dealing specifically with Spreadsheet problems and solutions.

Introduction to Engineering Computing or Engineering-12 in the second semester would prepare students to solve some of the most intricate Engineering problems. For many years it was Fortran that dominated, and many readers will remember the unforgiving aspects of this High Level program. Developed by programmers at Bell Labs in the 1970's, a new language called C made its debut which was followed by C++. Then in the late 1980's a powerful new program was introduced called MatLab. Developed by The Math Works Inc. company, it gave faculty, students and engineers in industry a powerful new tool to solve and model many engineering problems. MatLab is available in most technically advanced countries in the world and has powerful toolboxes for numerous applications and designs.

To demonstrate the usefulness and simplicity of Excel , a few examples of required problem solutions will be shown and since graphs demonstrate what happens over time in a process, much of the student class work consisted of graphical solutions.

When one compares the programming languages of MatLab and C++, it will be very clear how much quicker a program can be written in MatLab, how much more user friendly MatLab is, and how Engineering solutions are a fit for MatLab.

2 EXAMPLES OF EXCEL APPLICATIONS

Once the basic commands and the input and output have been mastered by each student, graphs of various types can be drawn. It is important to recognize if information should be shown with a scatter graph, a pie chart, or other graphing techniques. Since scatter graphs are the most useful for many processes, here the decision has to be made to use linear exponential, power or polynomial graphs and trendlines will confirm which one should be used. The student should also recognize if rectilinear, semilog or log log graphing is most appropriate. In the demonstration shown below, the change in capacitor voltage is given as the typical time constant curve, but the voltage can be read more easily on the semilog curve.

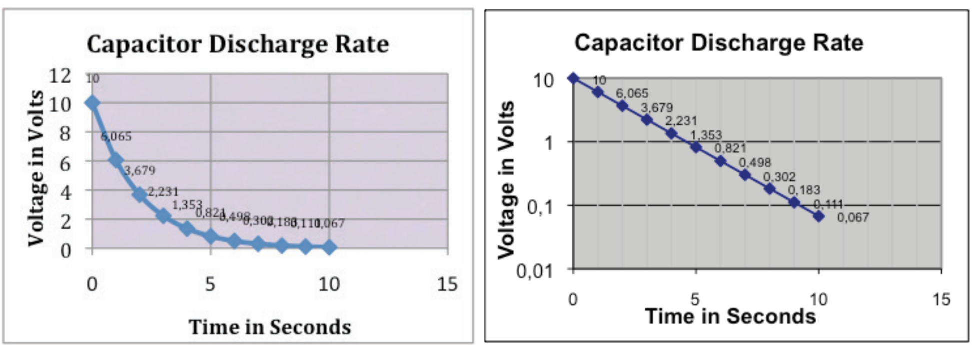

FIGURE 1. *Comparing a rectilinear graph with a semilog graph.*

As can be seen from Figure 2. , solutions of simultaneous equations can be performed quite easily using matrix inversion. This is especially useful in basic Electrical Engineering problems, where any order of determinant can be solved with multiple Voltage or Current sources. To make sure that values are not just copied into a spreadsheet, a second output sheet is required that shows the applied equations. In the sophomore year, students that have to take Linear Circuits and Systems I, have the option to submit homework problems that involve mesh or nodal analysis with the method shown.

			A- Matrix			B-Vector
6X1 - 5X2 -1X3 - 6X4 = 0	6	-5	-1	-6		0
-2X1 +2X2 - 2X3 - 2X4 = 1	-2	2	-2	-2		1
-1x1 - 1X2 + 1X3 - 2X4 = 1	-1	-1	1	-2		1
-7X1 - 3X2 - 8X3 + 4X4 = 4	-7	-3	-8	4		4

	Inverse Matrix				Solution	
0.070664	-0.01713	-0.27195	-0.03854		I1=	-0.443
-0.04497	0.192719	-0.19058	-0.06638		I2=	-0.263
-0.06852	-0.1349	0.233405	-0.05353		I3=	-0.116
-0.04711	-0.15525	-0.15203	0.025696		I4=	-0.204

FIGURE 2. *Solution of a Fourth order Mesh equation using inverse Matrix solutions in Excel.*

Since statistics plays an important role in most areas of engineering, the following problem will analyse in statistical terms Engine Cylinder Data. The statistical subroutine in Excel can show properties of central tendency, standard deviation either individually or in a summary table. Utilizing Bin and Frequency results can then be transformed into a Histogram.

Sample	Diameter in inches				Bounds	Sorted Data	
1	3.502		Mean=	3.5006	3.492	18	3.494
2	3.497		Median=	3.5	3.494	3	3.495
3	3.495		Mode=	3.497	3.496	5	3.496
4	3.500		Min=	3.494	3.498	2	3.497
5	3.496		Max=	3.509	3.5	8	3.497
6	3.504		Std.Dev.=	0.004272	3.502	11	3.497
7	3.509				3.504	13	3.498
8	3.497		*Bin*	*Frequency*	3.506	14	3.499
9	3.502		3.492	0	3.508	19	3.499
10	3.507		3.494	1	3.51	4	3.500
11	3.497		3.496	2		16	3.500
12	3.504		3.498	4		15	3.501
13	3.498		3.5	4		1	3.502
14	3.499		3.502	3		9	3.502
15	3.501		3.504	3		17	3.503
16	3.500		3.506	0		6	3.504
17	3.503		3.508	2		12	3.504
18	3.494		3.51	1		10	3.507
19	3.499		More	0		20	3.508
20	3.508					7	3.509

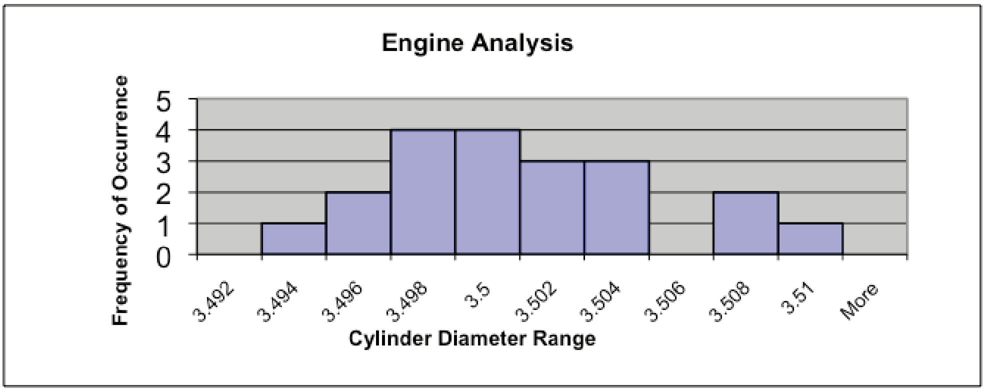

FIGURE 3. *Analysing Engine Cylinder Data with the Excel subroutine package.*

The examples that were given only show a small portion of all of the problems and the graphs that were solved and written in Excel in Engineering 11. Other significant problems included stress and strain data that was generated in the laboratory portion of the course and then transformed to scatter graphs. Solar panel installations for cities of various sizes were modeled so efficiencies of solar cells and amount of land use could be read from a Table.

A significant side benefit of the student involvement in solving problems in Engineering, Math, Physics, Energy, Economics, and Statistics was the extremely high attendance rate for each period and the very favorable ratings given at the end of the course.

3 PROGRAMMING LANGUAGE CHOICES

Introduction to Engineering Computing is the second course in the Engineering course sequence on computing and is also always taught in computer labs. In some ways the title is incorrect because much computing has been done in the previous semester. The student is introduced to both MatLab and C++ and the overwhelming choice each year, on which one they prefer for solving engineering problems, it is always MatLab. Let us look at the reasons for this and why MatLab is the better choice.

When one signs into MatLab, the window that comes up is the Command window. It is very similar to the display of a calculator and it takes only a few minutes to be able to navigate within the window. Equations can be written and solved, plotting can be done with a few keystrokes, and programs can be written but not saved at this point. Mistakes can be corrected by using the up arrow key or transferring information from the History window. Permanent programs can be written with script files, can be modified with ease and can be published. Troubleshooting a program or finding a mistake in the Command window display is usually quite easy because the MatLab debugging process indicates where the error is located and what type of error it is. Syntax errors such as omitting a parenthesis or a comma or spelling a command incorrectly, are the most common and will be easy to detect with the debugging process.

Let's compare what happens in MatLab to what occurs in C++. There is no Command or History window in C++. Header files are necessary for each program written in C++ and are one of the sources of errors. Compilers are not always completely compatible and switching from either Borland to Microsoft or Developer compilers can cause some real difficulties. Many of the C++ functions or arguments are abstract and have no basis in previously learned computing. Each variable has to be declared and the much used parenthesis and curly brackets in each program are difficult to spot when one is used for the other. After correcting each error the program has to be always recompiled. Students have great difficulties in understanding error messages and trying to correct what seems to be an error can lead to more errors. To print the results of a compiled program means to copy it to a Word program and then print it. One could go on and on pointing out deficiencies of one language compared to the other but that would be futile. C++ is a powerful high level programming language and has abilities to solve and model many intricate problems, however for Engineering, MatLab is the language that is preferable.

4 COMPARING MATLAB AND C++ PROGRAMS

Running a quick comparison between a formal way of using the quadratic equation in MatLab and in C++, but please note that this does not tell the whole story as the solution to any polynomial tells below.

```
% Solutions using the Quadratic Equation
 avalue=input('a=');
 bvalue=input('b=');
 cvalue=input('c=');
 answer1=(-bvalue+sqrt(bvalue^2-4*avalue*cvalue))/(2*avalue);
 answer2=(-bvalue-sqrt(bvalue^2-4*avalue*cvalue))/(2*avalue);
 disp('For Positive Squareroot =')
 disp(answer1)
 disp('For Negative Squareroot =')
 disp(answer2)
 if (bvalue^2-4*avalue*cvalue)<0
disp('Answer is complex')
 else
 end
```

FIGURE 4. *MatLab Program of the Quadratic equation.*

```
% Quick solution to any polynomial          % Quick solution to a fourth order polynomial

 x=[2,-5,12];                                y=[4,-3,20,12,-40];

roots(x)                                     roots(y)

ans =                                        ans =

 1.2500 + 2.1065i                            0.4898 + 2.5445i ,     0.4898 - 2.5445i

 1.2500 - 2.1065i                            -1.3406 ,     1.1110
```

FIGURE 5. *The need for the Quadratic Equation only arises if it is to be displayed.*

```
//The Quadratic Equation in C++
#include <iostream.h>
#include <iomanip.h>
#include <math.h>
int main ()
{char KW;
float a, b, c;
cout<<"Enter Values for a , b , c;\n";
cout<<"a = "; cin>>a; cout<<"b = "; cin>>b; cout<<"c = "; cin>>c;
double SQRT = pow( b , 2.0) – 4*a*c;
double Answer1=sqrt(SQRT);
if  (SQRT<0)
cout<<" The Answer is not real";   else;
double Root1= (-b + sqrt( pow(b,2.0) – 4*a*c )) /(2*a);
double Root2= (-b - sqrt( pow(b,2.0) – 4*a*c )) /(2*a);
cout<<"Root1 = "<<Root1<<setw(20)<<"Root2 = "<<Root2<<endl;
cin>>KW;
return 0;     }
```

FIGURE 6. *The comparison of the C++ quadratic equation program to MatLab but there is no short cut.*

Calculations involving complex numbers is usually an involved procedure, but MatLab handles those type of problems with ease . It would be a type of program one would not even attempt to try in C++ introductory analysis.

```
% Using the Format Method of writing complex Mesh equations
% (5-j5)I1 - (1+j0)I2 = (5-j5)
% -(1+j0)I1 + (3+j3)I2 = (-10+j5)
Amatrix = [(4-5i),-(1-0i);-(1+0i),(3+3i)];Bvector=[(5-5i);(-10+5i)];
LoopCurrents=Amatrix\Bvector
% Converting from Rectangular to Polar Values
PolarMagnitudes=abs(LoopCurrents)
AngleRadians=angle(LoopCurrents)
DegreeAngle1=180*(.3599)/pi
DegreeAngle2=180*(1.8383)/pi
LoopCurrents =   0.7372 + 0.2774i  ,  -0.6642 + 2.4234i    AngleRadians =   0.3599 ,  1.8383

PolarMagnitudes =   0.7877  ,  2.5127    DegreeAngle1 =  20.6208    DegreeAngle2 =    105.3268
```

FIGURE 7. *A MatLab Script program which calculates Loop currents in rectangular and polar values.*

5 CONCLUSIONS

The choice of Excel as the first Application Program/ Programming language made it possible for freshmen to start solving problems in Engineering from day one, since most of them had experience with the program in high school. In Engr-11 many problems were solved and modeled and students enjoyed obtaining solutions fairly quickly in many engineering areas, in statistics and in energy related areas. Tests and the final exam always had several questions that had to be solved using Excel and most students did well on them.

The second semester programming course concentrated on MatLab with an introduction to C++. The time allotted to each portion was about 10 weeks to MatLab and about 4 weeks to C++. It should be obvious from the examples and the simplicity of using MatLab, which is the preferable program to be used for Engineering Programming. At the end of the semester students were very candid about which program they preferred and some of them even went as far as saying they hated using C++ for solving assigned problems. MatLab was used in the sophomore year in Linear Circuits and Systems I and II and Design of Electronic Circuits to solve and simulate problems of Mesh and Nodal Analysis, Laplace transform and modeling of diode and Field Effect Transistors.

6 ACKNOWLEDGEMENTS

I would like to thank my wife Celeste for reviewing the paper, making helpful suggestions and pointing out errors in spelling and grammar structure.

The students at Pitt Bradford who voiced their opinions freely about the use of Excel, about the advantages of Matlab compared to C++, and thereby contributed to the rationale of this paper.

The Faculty Dev. Committee who provided monetary support to attend the conference.

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245 TESLA TURBINE AS A STUDENT LEARNING TOOL

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ABSTRACT

The aim of this paper is to present an example of a challenging engineering project given to students in their final year of study, as it embodies all the facets of engineering research and through this, facilitates student's learning by self discovery. Challenges include a literature survey, formulation of the principal analytical elements of the flow mechanism, designing of the machine, liaising with the workshop during its manufacture, helping in its assembly and testing, data generation, analysis and interpretation. Finally, writing an engineering report rounds off the exercise considered by this author to be a valuable pedagogic tool because of the above challenges that prepare the student for the next step: working in industry or follow a research path. The turbine was built and designed in the UWS School of Engineering based on the patent lodged by Nikola Tesla in 1913 and was used in the study of different aspects of its operation by several generation of students under the author's supervision. This paper focuses on the pedagogical aspects of the project topic and offers comments that highly endorse this type of approach when deciding on the type of a project for students to tackle.

Keywords: Self learning, discovery, pedagogy.

1 INTRODUCTION

Final year students of Mechatronic/Mechanical Engineering at the UWS are required to engage in a major project, either as a group for those whose academic record to date indicated preferences for team application – or individual projects for those who showed potential for research and eventual postgraduate study. Tesla turbine project was offered to the latter group over several generations of students [1]–[3] looking at different aspects of the machine. These included, analytically describing its operation, experimentally verifying essential theoretical assumptions, designing the machine from the first principles and finally, manufacturing it. The latter task involved assembly and commissioning the assembled machine. Common to all facets, as in all research undertakings, was the literature survey, formulating the physics of the operation if applicable, machine design, manufacturing, commissioning, experimental design, data gathering, data analysis and interpretation followed by conclusions, and recommendation for tackling the next step. The aim of this paper is to present highlights of students' endeavour in these exercises and comment on the project's pedagogical impact on the participants.

2 THE PROJECT OVERVIEW

The project topic was chosen because of its tractability, simplicity of construction well within the scope of the University's Engineering Workshop expertise, and appeal to students who showed a special interest in Thermofluids Engineering. It also contained most other elements that had been studied in prior years and therefore presented a student with a challenge creatively to synthesise this information which will clearly indicate his or her potential as to what next big step to make – a career in Engineering Research or Industry.

While a study of conventional turbines is a challenging task because it involves momentum transfer across curved blades, the Tesla turbine, Fig. 1, is much simpler because of inherently different concept and mechanical construction and therefore operation. It has a series of parallel discs mounted on a shaft and engaged by a peripheral jet of fluid initiating motion of the shaft through a viscous boundary layer interaction.

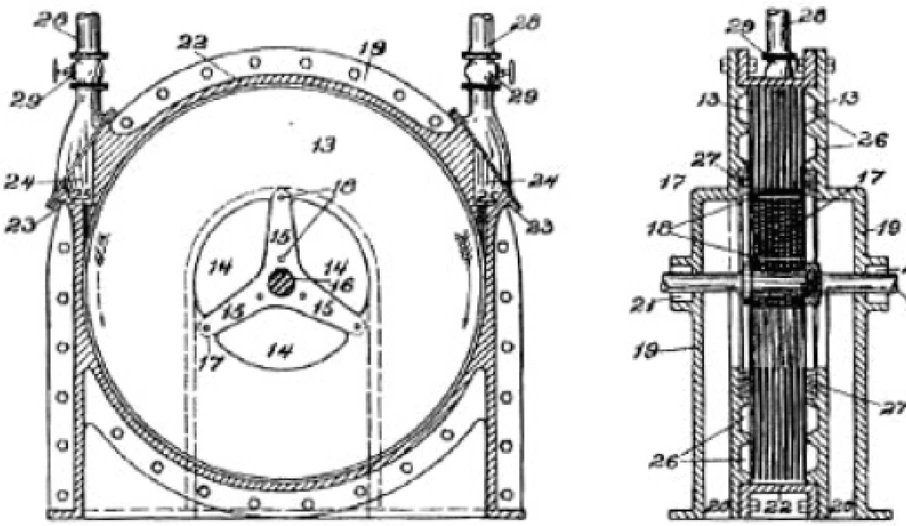

FIGURE 1. *The original Tesla Turbine Concept (Tesla Turbine Patent 1,061,206, May 1913).*

3 PEDAGOGICAL ELEMENTS

Independent, self driven study, is best sustained if the mentor provides support whenever needed to ensure the student remains motivated. Thus, while a student often pick the topic rather than the supervisor (a mistake!) – this aspect is not at all addressed, leading to student's own ultimate (or potential) lack of optimal performance. An important factor in this is the practical relevance of the topic offered for the student to pursue largely on his/her own. In Engineering this is relatively easy – and carries a lot of appeal with most students, who are eager to apply themselves hands on to something "useful"!

Role of the teacher as a mentor, guide and sustainer of the student's enthusiasm is paramount to teasing out from him/her the optimum academic performance. The bond established between student and teacher at this stage often continues into his/her first employment, where mentor's reference often carries a decisive weight in facilitating a premier job placement. It is often not stressed enough to students that they start building a roadway to their career principally in the senior years at the university. Acquiring appropriate habits and attitudes established at the late stage of their course is highly conducive to successful professional careers afterwards.

Providing the right amount of academic guidance is also a challenge, as "spoon feeding" is highly detrimental to one's professional, development leadership and independence as it destroys self-confidence as well as demeans one's self image, whilst arguably providing a temporary fix for the tempted student.

Since this apparatus nor the mechanism of its operation is not covered in the fluid mechanics undergraduate texts, students have to apply their understanding of the subject to pursue their own investigation with only a minimal guidance from their supervisor. Thus, ideally - they are driven by their own awakening professional curiosity, whose own momentum needs to be not only recognized but engendered by their supervisor.

The project progresses through the well established steps once the decision is made to follow it up: literature survey, analytical formulation of appropriate mechanism of operation to provide an understanding of the physics, and theoretical background. This is sometimes followed up by a numerical modelling exercise, which could well be where the projects ends. Some chose a physical model, involving the design of machine elements, using CAD to prepare workshop drawings. Liaising with the workshop staff making the parts is also a part of the training. Assembly, commissioning and finally data collection, analysis and interpretation precede the writing up of a comprehensive report (thesis).

An example of the generic elements contained in the Tesla Turbine project are illustrated below.

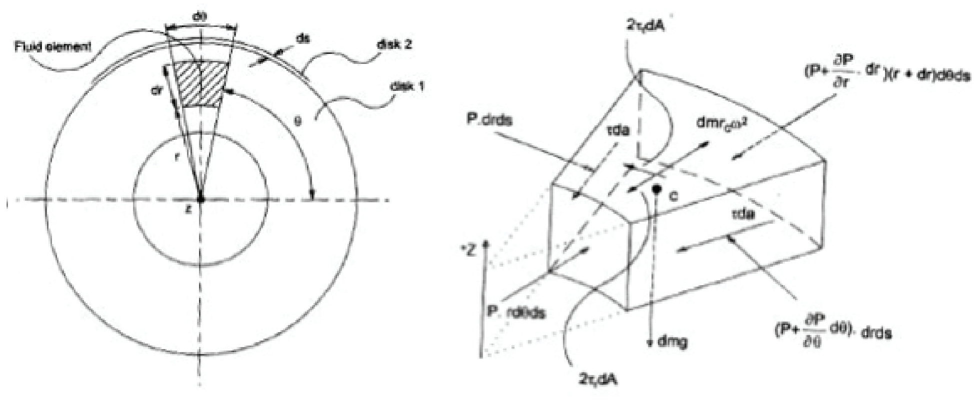

FIGURE 2. *Analytical reasoning ab ovo.*

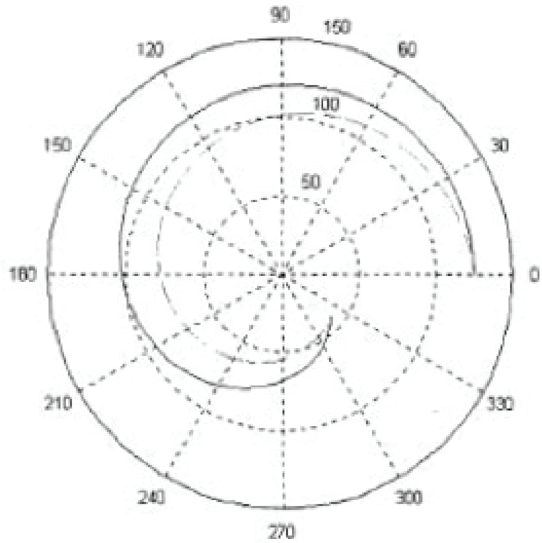

FIGURE 3. *Flow streamlines: experimental and theoretical (dashed line, hitherto assumed).*

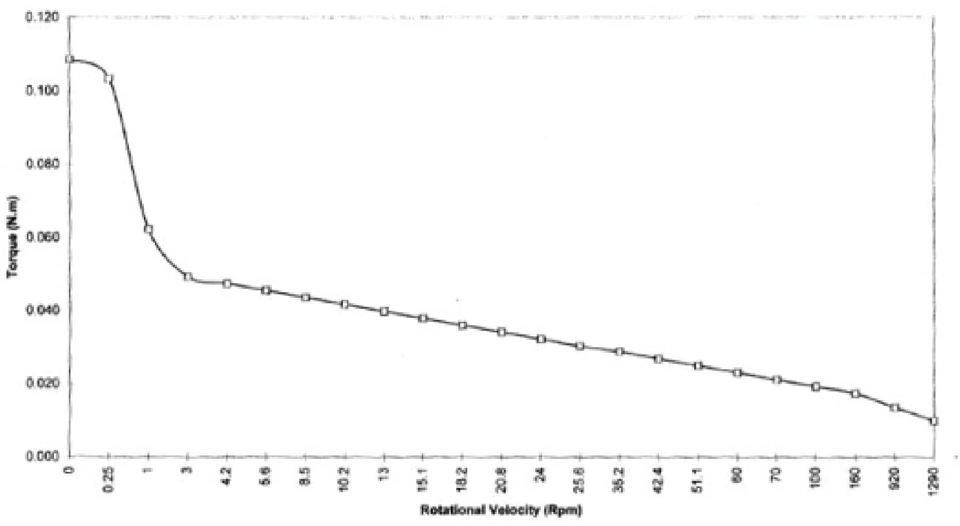

FIGURE 4. *A typical turbine performance curve.*

4 INNOVATION AS THE LEARNING FOCUS

While it is expected to end up with the aimed outcome, the process of getting there is in itself an important aspect of the whole exercise. Thus, the emphasis is on quality rather than quantity: while timeline is important – even of greater importance is how well the time was used to reach the stage at which the student is at the end of it in terms of quality. While completion is desirable, even more so is the quality of the process of getting there, as it encourages innovation having the objective in the focus. It is at this stage of their studies that students are given the opportunity to meet the end objective in an optimal manner – having gone through the rigours of the machine design process to which they were exposed in the previous years.

Having been subjected to structured learning to date, the student experiences for the first time the intellectual freedom to exercise his/her imagination to achieve the objective aimed at, with enough professional maturity to realize what is within the realm of that which is currently deemed possible. It is this creative aspect in the human spirit that is not given enough emphasis in engineering courses generally – the apparent lack of which erroneously paints engineering as a "dull" course. Attempts to address this earlier

have been made by rare institutions which have introduced humanities as an integral part of an engineering curriculum, as they are the traditional source of creativity.

5 LESSONS FOR THE FUTURE

Given complete freedom of application and given the target outcome, nurturing

self reliance, creativity and responsibility for own decision are important by-products of an exercise of the type described. Improved technical communication at the professional level through comprehending fully what is wanted, what are the operating parameters delineating the task to be accomplished and coming up with a product of a professional caliber are also valuable skills in the professional life the student is about to embark upon.

Appreciation of the importance of technical communication and organized manner of its application finally provides justification for seemingly "useless" first year subjects that first taught students rudiments of how to communicate effectively.

Finally, learning how best to manage time given for the completion of the projects

completes the array of attributes expected of a professional engineer, so effectively addressed in projects of the type described here.

6 CONCLUSIONS AND RECOMMENDATIONS

Judicious selection of a challenging topic is predicated for a holistic educational experience such that it has all the elements of a real-life research undertaking: literature survey, background theory analytically formulating the basic physical principles; design of the item of interest from concepts to the working drawings using CAD software; liaising with the workshop during the manufacture of the designed object; assembly of components into the designed machine and its commissioning; data generation, its analysis and interpretation, and finally, writing a report. In the absence of a competent workshop, sometimes computer modelling exercise is resorted to, though not favoured by this author because it does not effectively replace the hands-on experience.

The principal pedagogical outcome taken as an embodiment of all the elements that go into creating a competent engineer, is a high level of professional maturity at the end of the four year course in preparation of joining the work force.

The described project illustrates a highly successful approach of student learning through self discovery, highly recommended as an effective way of training future leaders in the profession.

7 ACKNOWLEDGEMENTS

The author thanks his senior students Michael Mihovilovic, Amitkumar Akbari and Bruce Davy for dedicated effort they put into their projects. Michael first came with the idea as well as designing and building the machine himself with some help from the School's Machineshop.

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246 INNOVATION COMPETENCES IN GAME TECHNOLOGY EDUCATION

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ABSTRACT

The structural change in western societies has forced universities to update their curricula especially in engineering faculties. For example in Information Technology links to future technologies in fields such as renewable energy, wellness and games are and will be sought when designing and updating curricula. In this paper, the challenges and possibilities of ubiquitous computing and 3D virtual models are introduced as a part of the process of updating the curriculum of Information Technology, especially in the specialization area of Game Development. Ubiquitous computing and geoinformatics will offer the game industry tools for new innovations. Motion sensing and mobility will form the basis but ubiquitous computing and geoinformatics will facilitate innovation competencies globally. New technologies will force universities to consider human resources and investments, too. In this paper, these challenges will be analyzed in order to identify the excellence in global competence.

Keywords: Curriculum, Learning Outcomes.

1 INTRODUCTION

The game industry is one of the most rapidly growing sectors. According to Reuters [1] the size of the global game market revenue was around 65 billion dollars in 2011 up from 62.7 billion dollars a year earlier. At the same time, universities face challenges to define their curricula up to date, based on requirements of the industry. The International Game Developers Association (IGDA), as an independent and non-profit organization, has worked years between universities and the industry. Study of games is an interdisciplinary area and, for example, in the United States there is no accreditation for undergraduate university degrees in games [2]. Gaming culture as a part of generation y has been influenced by cultures such as rap music, break dance, and graffiti in which individualism, liberality, and self-expression are characterized. In this context, universities and other pedagogical institutions have challenges to operate. Moreover, the future of gaming will be solidly mobile [3]. That is, high-quality games will be played anywhere, and any-time. Therefore, it is essential to notice that the game industry needs experts not only in graphical design, manuscripts, audio-visual design, and programming, but also in new fields of expertise, namely in ubiquitous computing, and geoinformatics.

In this paper, the challenges and possibilities of ubiquitous computing and 3D virtual models are introduced as a part of the process of updating the curriculum of Information Technology. In addition, we will present Game Development as a part of the curriculum structure in the B.Eng. Degree Program in Information Technology at Turku University of Applied Sciences (later TUAS). The curriculum has been developed for years based on the CDIO (Conceiving – Designing – Implementing – Operating) initiative [4]. Next a background for this research will be introduced, followed by a short state-of-the-art review and a comparison of core topics of Game Development in 48 universities. Finally, these findings will be shortly analyzed.

2 BACKGROUND

As a background for this research, the information and communication technology departments of three higher education institutions in Turku, Finland have worked in the same building since 2006 and cooperated in education and research. One of the results in this cooperation has been the so-called ICT ShowRoom event which is a student project exhibition and competition open to all students of the joint campus. This event has become an established and integral part of the academic year gathering students, staff and industrial representatives together [5].

Furthermore, our curriculum in Information Technology has been developed systematically based on the CDIO standards. For example, the recent problem-based learning (PBL) implementation of the first semester course in Product Development has been successful [4]. The first-year students have faced a learning assignment each week, and these assignments have been solved and reported according to the PBL cycle. Several courses contain PBL learning assignments. Currently, our curriculum will be further developed from various perspectives. In this paper, we will focus on Game Development as a new specialization area in the curriculum. In addition, the third-year curriculum will be updated towards the objectives in the Capstone Design initiative [6]. This process will be utilized also in Game Development education in order to offer our students experiences on real life projects.

Game Development will be one of the specialization areas in our curriculum from autumn 2012. The former Digital Media specialization area will be replaced and a part of its content will be utilized in this new specialization. Currently, the game industry in Turku area is relatively small in terms of the size of companies and number of employees. However, structural changes in the Finnish telecommunication industry have forced us to find new business opportunities. Finnish know-how in telecommunication and mobile computing offers the game industry an opportunity to re-educate highly educated engineers. Game technologies have already been taught in small scale in our university in cooperation with the University of Turku and industrial partners.

3 PERSPECTIVES ON GAME DEVELOPMENT

3.1 State-of-the-art in Game Development

The game industry is currently switching over to the eighth generation of video consoles. The first next generation video console was announced June 2011 in E3 Expo in Los Angeles. This console still relies on motion sensing. On the other hand, its remote controller has similarities with mobile gaming. According to Geekophone's [3] studies the future of gaming has characteristics such as mobility, ease of publishing, and the rise of female gamers. They have estimated the business profit in mobile gaming industry to rise from 8 billion (2011) to 11.4 billion (2012) dollars. The change in game publishing has opened new business opportunities.

Digital distribution gives developers a possibility to publish games without a publisher. This change is a significant improvement over the old model. Earlier developers shared usually just around 8-15% of revenues and nowadays revenue can rise up to 70% [7].

Mobile phones (or later smartphones) have evolved from embedded devices to efficient computers. The latest releases of iOS, Android, and Windows Phone devices can be characterized with features such as high resolution displays, efficient central processing units, graphics processing units for 3D visualization, gigabytes for data storing, and sensors for positioning and sensing. All these features will open new opportunities for game developers. For example the use of 3-axis accelerometers and digital compasses can be used for user actions such as activity recognition, and fall detection. The above mentioned sensors together with WiFi radio, smartphones can be used for accurate indoor positioning. Bluetooth or RFID (Radio Frequency Identification) radios are able to detect objects nearby. The microphone, in turn, opens possibilities to detect silence, noise, or loudness. Respectively, the camera can be used in augmented reality applications.

Game developers can also utilize external sensors. Actually, ubiquitous computing will enable gaming anywhere, anytime, and to anything. It will be embedded into the objects of everyday life, and it will be invisible to the users or accompanied by new form-fitting solutions (cf. [8]). Sensors can be embedded to the players' environment. The environment can be instrumented with RFID readers which are able to detect players or other game objects. The use of wireless sensor networks enables, for example, voice or motion detections in challenging conditions without cables and electricity plug-ins.

Geoinformatics as a field of science is nowadays utilized everywhere from intelligent transportation systems to car navigation, from military operations to ambient assisted living. It will also offer the game industry tools for building bridges between the real and virtual world. For example, Navteq True system is currently collecting laser scanned information all over the world. Based on this information the game industry is able to utilize point clouds not only in traditional game fields but also in augmented reality games, in wellness games, or in serious games. Nokia's City Scene is an example of applications which utilize laser scanned information. For game developers this kind of approach opens new interaction methods on the maps by finding what a building contains with a click, or by showing information on building facades [9].

3.2 Core Topics in Game Development

As mentioned above, IGDA has worked years between the game industry and universities. One of their goals is to facilitate the development of educational programs. In fact, IGDA has published a curriculum framework in 2008 to assist educators and students from the creation of individual courses to the development of full degree programs [2]. This framework has been used in this paper as a basis of the curriculum design related to the specialization area of Game Development. On the other hand, this framework has been published four years ago and a part of the topics discussed above are not included in the core topics of the framework. According to IGDA [2] core topics can be classified in three categories: game design, game development, and game studies. The set of core topics has been proposed as follows:

1. Critical Game Studies
2. Games and Society

3. Game Design
4. Game Programming
5. Visual Design
6. Audio Design
7. Interactive Storytelling
8. Game Production
9. Business of Gaming

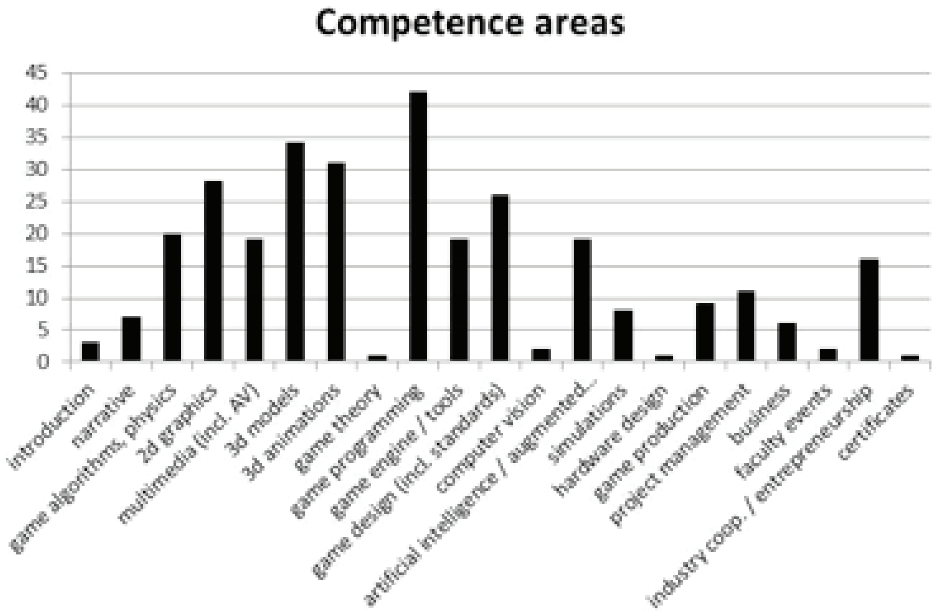

FIGURE 1. *A comparison of curriculum topics in game education.*

In order to identify relevant topics for our curriculum, we decided to explore what kind of game design, game development, and game study courses different universities (n=48) currently provide in their Bachelor's and Master's Degree programs. The main part of the selected degree programs are English-language programs (especially from the US, and UK). The comparison included universities also from the Netherlands, Denmark, Norway, Australia, Malaysia, and the Philippines. We have classified the courses in 21 categories (Figure 1). These categories are not classified based on IGDA's framework, because the information which was available in the internet was varying in the level of details. Thus, we are only able to compare the results presented in Figure 1 to IGDA's framework. Results in this survey are in line with IGDA's core topics presented above.

3.3 Game Development Specialization Specific Competencies

According to the European Commission [10], learning competence means "the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development". The European Commission [10] has defined levels in the European Qualifications Framework (EQF) which has been used as a basis for the Finnish National Qualifications Framework (NQF). Our curriculum in Information Technology is a Bachelor's Degree Program classified in level 6 in the NQF [11]. The basis for the curriculum design work has been presented in various publications. First of all, our curriculum has been designed based on the CDIO initiative [4]. Our subject-specific competencies for all specialization fields, in turn, have been presented in [12]. The following Game Development specialization specific high-level competencies have been designed based on EQF and NQF requirements. In the design work, we have also utilized IGDA's framework and the results of the comparison presented above.

Game Development: Game business and services expertise

- [the graduate] understands the characteristics of game business
- is able to produce content to game business services considering the different customers
- can utilize software development methods in service production
- is able to use different distribution channels efficiently
- possesses skills to lead people, processes and projects in a product development organization

Game Development: Proficiency in Game Development

- [the graduate] knows the most important standards of the fields
- is familiar with the different phases and technologies of game development
- masters the most important development tools
- knows the capabilities of different game platforms and is able to utilize them
- is able to work as a software development team member

3.4 Game Development in TUAS

Universities and other educational institutions face challenges in operating with generation y. Methods we are using are from the last millennium, and are not always relevant for students who are living in the digital world. We have worked in order to find solutions which would better fit students who are rather interested in individualism, liberality, and self-expression than passive and strictly structured learning methods. TUAS has defined innovation competencies just lately. The innovation competencies contain individual, community-oriented, and networking perspectives [13].

Next these innovation competencies are analyzed based on issues we have in the curriculum design. We have achieved positive and promising results ([4], [5], [14]) but there still are many challenges. We are moving towards a more collaborative way of teaching and learning. On the other hand, industrial cooperation in R&D projects in which the students are able to gradually take more responsibility is still challenging.

Action 1: To move towards more intensive industrial cooperation we will start the so called Capstone project. This course will be arranged in the third academic year, and students will work closely with local industry. One of the objectives is to encourage students to establish spin-off companies based on innovations they are creating.

Our curriculum has been developed based on the CDIO initiative and the Capstone project will be the latest step in this process. We believe that these changes will decrease the number of drop-outs and speed up graduation. Drop-outs are currently a significant problem in Finnish higher education. Especially the first two semesters are critical when studies are typically more theoretical and introductive.

Action 2: To decrease early drop-outs we have used Lego NXT robot kits in the programming courses and next semester also game engines (e.g. Unity 3D) will be introduced. This approach seems to give students more concrete understanding of which kind of opportunities programming will offer. In addition, we will introduce a new science course Game Physics which will not only give tools for the students in game development but also increase motivation towards science in general.

We have found that external objectives will motivate students to work more efficiently and intensively. Roslöf et al. [5] have introduced the so called ICT ShowRoom concept. As a result groups were motivated to keep up the pace during the project.

Action 3: In game development, we will focus on external objectives and we will be facilitating ICT ShowRoom locally for our students. In addition, they will be asked to send their project results to national and international competitions. Furthermore, we will enlarge our R&D activities related to game development in order to find new opportunities for the students to take more responsibility, and to work intensively with state-of-the-art topics with local companies and other stakeholders (cf. [5]).

Students seem to have difficulties with understanding the difference between development tool -oriented and technology-oriented learning. Based on industrial feedback, we have chosen Unity 3D and Microsoft XNA as development tools. Unity is a cost efficient approach for SMEs, and local industry is largely using this tool. The latter one is a strategic choice due to the presence of Nokia and Microsoft in this region.

Action 4: C# programming has been chosen as a main programming language in our curriculum. We will mainly use C# also in game development. In fact, Unity 3D supports C# and is currently the mostly recommended scripting language in this tool. In addition, we will study Microsoft certificates in game development. These choices will give students competence areas which will improve their value in the employee market.

In Figure 2, it is illustrated how these actions will strengthen students' capabilities to work in close cooperation with local industry and other stakeholders.

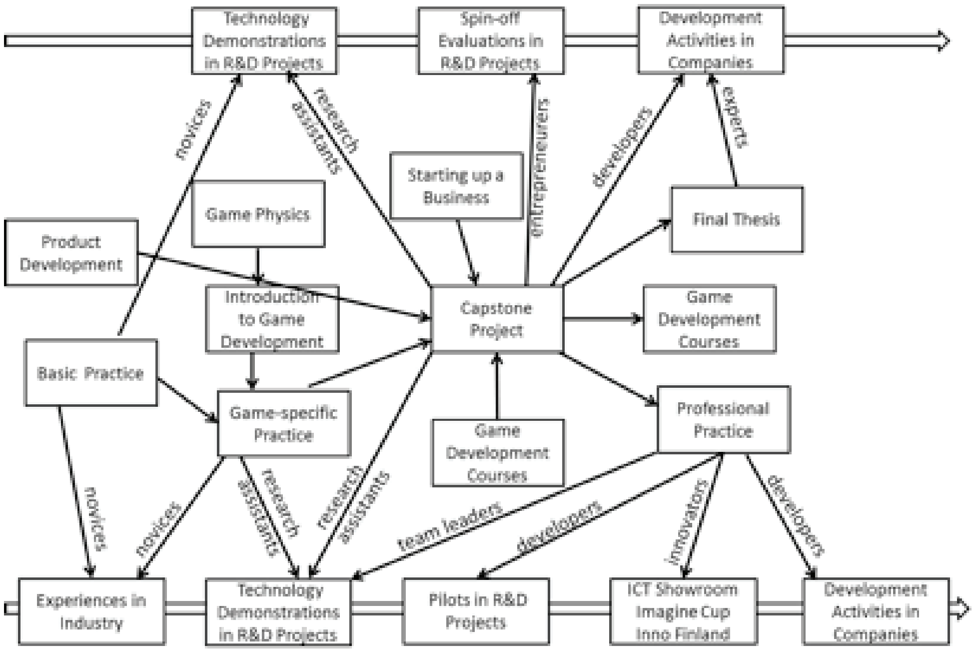

FIGURE 2. *Students' capabilities to cooperate with local industry and other stakeholders.*

4 CONCLUSION

In this paper, we have presented how the Game Development specialization area as a part of our curriculum structure in Information Technology at Turku UAS. The curriculum has been developed for years based on CDIO initiatives and PBL principles. The first students will start in the Game Development specialization next autumn. Especially in this area, new teaching and learning methods are needed.

Based on previous experiences, we have defined four actions in this paper. We believe that these actions will improve students' individual, community, and network-scale innovation competencies. Students will work independently, goal-orientedly, and efficiently. They will be working in R&D projects and with local industry in multi-disciplinary and multi-lingual teams. From the very beginning of their studies students will receive know-how on software development tools in a concrete manner. This will improve their understanding of technologies available for creating new innovations. These methods should strengthen their professional identity and abilities to cooperate with experts from other domains.

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249 NOVEL APPROACH TO ORGANIZE HIGHER EDUCATION IN REGIONAL UNITS

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ABSTRACT

We introduce one approach to organize higher education in regional units. The model is based on close co-operation with companies and on own local RDI in selected areas. Students start their studies in the main campus. Typically, during the second half of the curriculum considerable part of the studies consists of project-based studies, which are realized locally in authentic development projects in companies or in own RDI projects. In either case, teachers define the pedagogic goals for the projects and follow the learning process and the achievement of the goals. In common definitions project-based studies refer to the studies, which are close to the professional reality, emphasize knowledge application, are accompanied by other subject courses and accentuate the management of time and resources and the differentiation of tasks and roles. In our approach the strong involvement of potential employers should be added to this description.

Keywords: University-industry collaboration, enquiry-based learning, project-based learning.

1 INTRODUCTION

It is a common tendency in Finland to centralize higher education in large units in order to offer students a possibility to diversified studies and to strengthen RDI operations. This sets heavy pressure to regional units located apart from main campuses. However, especially universities of applied sciences have de jure task to serve regionally the working life in their own area.

One possibility to combine these more or less contradictory goals is to organize project-based education and practical training regionally as a part of the curriculum. In order to serve the needs of the region, local industry and commerce should participate to the design and implementation of the project-studies. This means close university-industry collaboration. Common RDI projects support and deepen the collaboration and implementation of the education. Due to this, local RDI functions on selected areas are seen as a key factor to the success of the education.

The proposed approach is currently put into operation in our branch campus in Raahe. The implementation demands changes in curricula in the main campus in Oulu as well. The major challenge is the new organizational culture that concerns both teachers and students and external associates. We give examples on the curriculum development and on the practical implementation of the learning projects. Preliminary estimates of the potential of the proposed approach and main steps and challenges in the implementation are discussed.

2 DEFINITIONS

Before the actual presentation of the novel approach basic terms related to the project-based learning are shortly defined. The learning of the students in the projects may have features from project-based learning, problem-based learning, active learning, collaborative learning, inquiry-based learning, blended learning, student-centered learning and so on. In the reference [1] enquiry-based learning (EBL) is used as an umbrella term to describe the approach to the learning that includes elements of enquiry. EBL as defined in [1] covers different approaches of problem-based learning, field-work, case studies and investigatios, individual and group projects and research activity. There is obviously overlap between these different approaches.

In this paper the term project-based learning is used to describe our approach. The basic definition of the term comes from Adderley et al. [2], who define the following features as typical to project based learning:

1. It involves the solution of a problem, though not necessary set by the student himself/ herself.
2. It involves initiative by the student or group of students, and necessitates a variety of educational activities.
3. It usually results in an end product (e.g., report, computer program).
4. It often goes on for a considerable period of time.
5. Teaching staffs assume advisory roles instead of authoritarian.

We add to this definition:

6. It emphasizes the management of time and resources and the differentiation of tasks and roles.
7. The objectives of the projects are defined and the projects implemented in close cooperation with industry and other employers.
8. The clear pedagogic goals are set to every project and the realization of these goals is evaluated after the project.

Mills and Treagust [3] have listed the major differences between problem-based and project-based learning. According to these:

- Project tasks are closer to professional reality and therefore take a longer period of time than problem-based learning problems (which may extend over only a single session, a week or a few weeks).
- Project work is more directed to the application of knowledge, whereas problem-based learning is more directed to the acquisition of knowledge.
- Project-based learning is usually accompanied by subject courses (eg. maths, physics etc. in engineering), whereas problem-based learning is not.
- Management of time and resources by the students as well as task and role differentiation is very important in project-based learning.
- Self-direction is stronger in project work, compared with problem-based learning, since the learning process is less directed by the problem.

3 NEW APPROACH TO ORGANIZE EDUCATION

Oulu University of Applied Sciences has main campuses in Oulu and regional campuses in Raahe (80 km southwest from Oulu) and Oulainen (100 km south of Oulu). Engineers are educated in the School of Engineering in Oulu and Raahe. The total number of engineering students is approximately 2800 of which 2500 study in Oulu and the rest in Raahe.

3.1 Historical background

The engineering education was started in Raahe in 1972 when Institute of Computer Science was founded. This was one of the leading institutes in computer science in Finland throughout 1970s and 1980s. The volume of the education was increasing rapidly during the second half of the 1990s mainly due to the influence of the incredible growth of Nokia. After the dot-com bubble the need of new IT engineers was decreased as well as the interest of the applicants to the IT education. This meant difficulties especially in regional units whose attraction was considerably lower than of those units located in larger cities. The amount of students in Raahe campus during the last ten years is shown in figure 1.

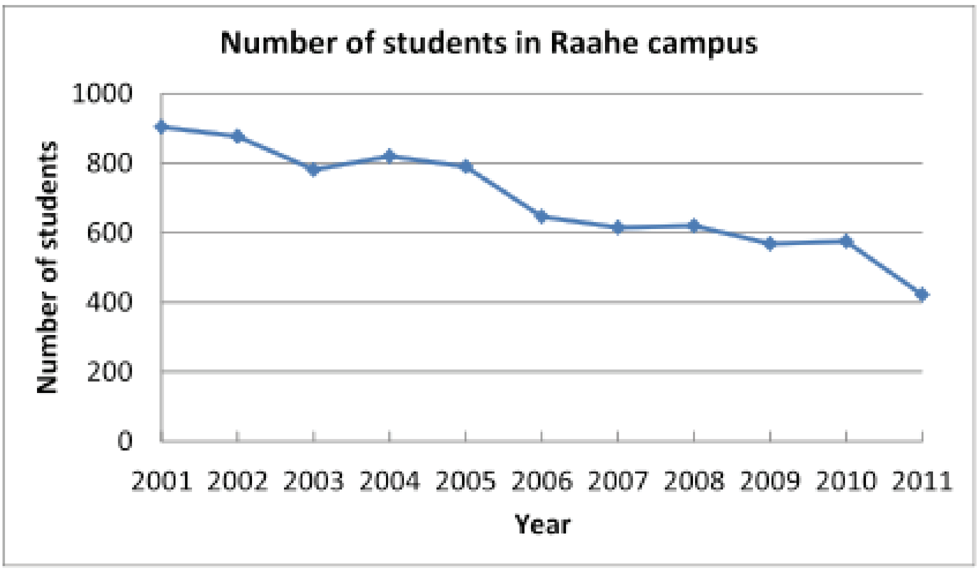

FIGURE 1. *Number of students in Raahe campus.*

Because of decreasing attraction and volume it was obvious that some actions had to be taken. In 2009 Raahe School of Engineering and Business was joined to the School of Engineering in Oulu. At the same time the decision was made to end the annual intake of students in Raahe and the development of the new study model was launched. Currently one adult education group of thirty students starts annually in Raahe. In addition School of Engineering executes there continuing training and research and development projects according to the local needs. Some milestones of the higher education in Raahe campus are shown in table 1.

TABLE 1. Milestones in higher education in Raahe campus.

Year	Event
1972	Raahe Institute of Computer Science was founded
1996	Oulu University of Applied Sciences was founded
2002	Raahe School of Engineering and Business was founded
2009	Raahe School of Engineering and Business joined School of Engineering in Oulu
2011	Degree programmes in business administration and business information systems joined School of Business and Information Management
2011	Intake of new students ends
2012	Advancements in new approach

3.2 Key elements of the new approach

All the new students start their studies in Oulu campus. After two years they have possibility to participate practical training projects implemented in co-operation with employers (figure 2). Part of these projects are realized in Raahe and conducted by the teachers of the Raahe campus. The amount of the students is strongly determined by the needs of the local companies and the activity of local teachers. It is obvious that the operational environment of the teachers shifts from the classroom to the field near the employers. At the same time the role of the teacher shifts towards mentoring the professional growth of the students. In practice this means considerable change in the organizational culture of the institute as well.

FIGURE 2. *Key elements of the new educational approach.*

3.3 Curriculum development

In order to make possible to students to participate to studies in Raahe suitable curricula had to be developed. At the first phase these were implemented in the degree programme in information technology and in the degree programme in the mechanical and production engineering. This was obvious, because staff in both of these fields exists in Raahe. Now, all new curricula in the school of engineering must have considerable amount of project-based studies.

A typical structure of the new curricula is shown in figure 3. A bachelor's degree in the engineering fields takes four years (that is eight semesters). During the first two years the students train basic skills in sciences, languages, communication, economics and professional studies. As the studies proceeds the amount of the project-based studies, practical training and thesis work increases.

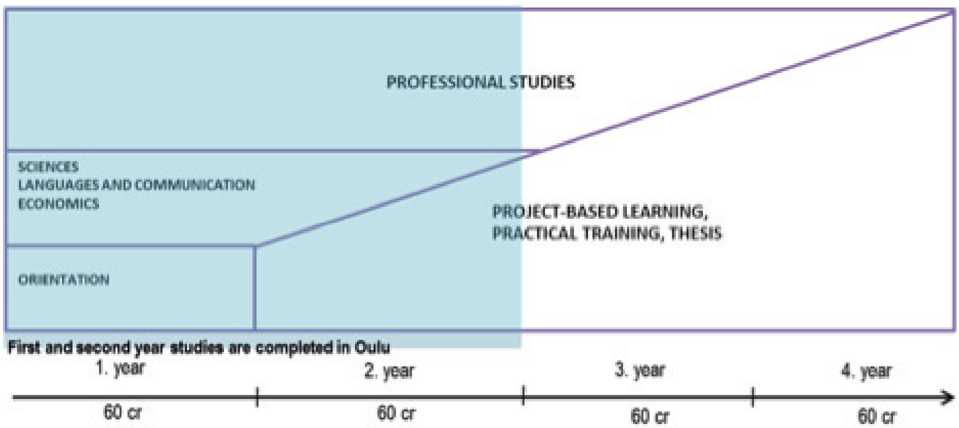

FIGURE 3. *Typical structure of the curricula.*

Typically, practical training projects consist of three separate courses each of 10 ECTS credits (figure 4). The first one takes place during the sixth semester and the next two courses during the seventh and eighth semester. In addition to the training projects, students involve in practical training (30 ECTS cr) and make a bachelor's thesis (15 ECTS cr) in close co-operation with companies.

Practical Training Projects					30
T746110D	Training Project 1	10			10
T746210D	Training Project 2		10		10
T746310D	Training Project 3			10	10

FIGURE 4. *Practical training projects in a typical curriculum.*

A description of the content of a typical training project is shown in table 2. The considerable amount of the supervision should be noticed. The supervision is performed by the teachers and by the project personnel in the company. In addition to the results of the training project itself students have to demonstrate their competence. This may be performed e.g. by an exam, an exercise work or a portfolio. The project may have technology related learning goals and other learning goals such as those related to communication or internationalization skills as well.

TABLE 2. Description of a training project.

T746210D	**Training Project 2 10 ECTS cr**
Language of instruction:	English
Learning outcomes:	In this course the students get practice in defining, planning, and executing a project. An objective of this course is to deepen the project working skills and at the same time improve the technical knowledge by working on different technical systems.
Contents:	The students apply their knowledge of software project methods and techniques and learn project planning, execution, documentation, and reporting. The technical skills needed and improved include software design, implementation (programming), and testing.
Prerequisites:	Not applicable.
Mode of delivery:	0 cr contact studies 0 cr virtual/distance studies 10 cr R&D-studies
Planned learning activities and teaching methods:	140 h Supervised work 125 h Independent work 5 h Demonstration of competence and assessment methods (for example exam, exercise work, portfolio)
Training:	Not applicable.
Literature:	The literature of the course will be announced later.
Generic competences to be assessed during the course:	International competence, Innovation and development activity competence
Assessment scale:	Grading scale 0 - 5.
Year of study and Semester/trimester:	4. year, autumn

4 PRELIMINARY EXPERIENCES

First pilots of the new model were run during 2011 in the degree programmes of information technology and mechanical and production engineering. Original plan to run in the model is shown in figure 5. At the moment, the number of the students and companies involved is slightly larger than planned and the feedback both from the students and from the companies is promising.

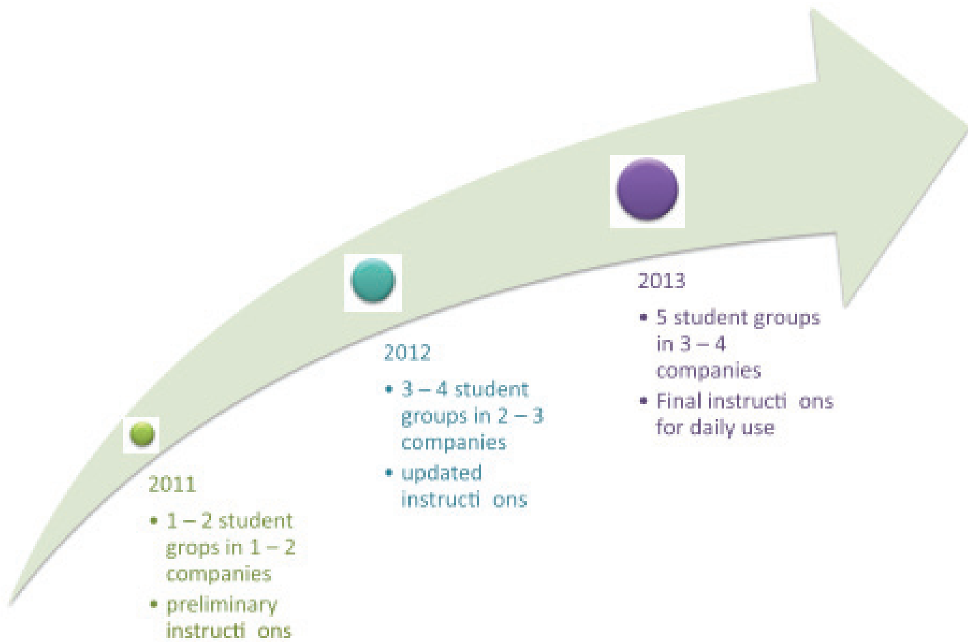

FIGURE 5. *Steps in the implementation of the project-based learning in Raahe.*

Teachers have noticed that the increased level of study motivation is leading to good learning results. On the other hand training projects clearly improve the possibilities of the students to find a place for the on-the-job training and find real-life subjects for the thesis work. This promotes the student's employment opportunities after the graduation as well.

5 CONCLUSION

While preliminary results are encouraging, some challenges are obvious. First, as already mentioned the new way of organizing the education requires change in the culture of the whole organization. This means new type of mindset both in Raahe, as well as, in the main campus in Oulu. In fact, it seems that the change is more difficult to the staff in the main campus. This is probably because the suppression of the activity concerns mainly the regional campus in Raahe and the circumstance is not so threatening in Oulu. Second, all the students taken in Raahe must have possibility to finish their studies there. In consequence, there is a period of four to five years where old and new approaches are realized in tandem. The motivation of the staff is obviously somewhat challenging in this situation. Third, the new approach is considerably dependent on the training positions in the local companies. The commitment of the companies will be determined in reality under a recession.

On the other hand, the potential of the new approach is significant. At its best, it ensures accomplished labour to the local industry and commerce. In the training projects the students can develop their skills according to the current needs of the companies. It looks, that during the next few years, there is a substantial increase in the need for the skilled labour in Raahe area. This is due to large incipient projects related to a nuclear power plant, wind power plants and mining. It is expected that these projects induce a demand for higher education and continuing training as well.

6 ACKNOWLEDGEMENTS

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252 EDUCATION TO THE TECHNOLOGY ENTREPRENEURSHIP IN ENGINEERING STUDY PROGRAMS IN SLOVAK REPUBLIC

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ABSTRACT

The contribution is orientated on understanding the innovation process in engineering study programmes related to theoretical and methodological backgrounds of the technology entrepreneurship and discussed ways that are used in the engineering education at the University of Zilina in the Slovak Republic. There are used several ways of technology entrepreneurship education, e.g. the optional courses and trainings, creation of cooperation networks, consulting services, workshops and forum of creative ideas, etc. It deals with the matter of legislation framework of this problem and its gaps in the Slovak Republic and at the university. The tool for monitoring the knowledge diffusion dynamics – knowledge biography and methodology for examining regional dimension are discussed. It is necessary for Slovak universities to increase co-operation between universities and business surroundings mainly in relation with innovative processes and in solution of high level of unemployment rate. University becomes an active element in business environment, in regional development and it declares responsibility and its place in modern society. The unemployment rate in the Slovak Republic is quite high, and so the entrepreneurial competences of students and graduates have to be developed, improved and increased. The engineering students and graduates are also the potential for innovations and for increasing the rate of high-tech industry in regions.

Keywords: Engineering education, entrepreneurship, competences.

1 INTRODUCTION

Discussions about study profiles and curriculum of technology university graduates resulted in acceptation of two significant documents of European and worldwide prominence [1], [2]. The professionals have no doubts that technology university students have to be given the knowledge from non-technology domains. The graduates or engineers have to be flexible, creative and responsible for consequences of his/her doings [3]. In addition the new social-economic conditions, especially those in the transitive countries, ask for a qualitatively new generation of specialists and professionals that will cope with the latest technological trends and will be successful in management of business subjects. For promoting the entrepreneurship spirit at university and for promoting the entrepreneurial competences of students and graduates the continual programmes and activities orientated on assistance and help towards students, researchers, departments, etc. transform new ideas into sustainable ventures or firms through training and incubation have been developed. The mission of the university in the research includes the effective transfer of knowledge and technology to the praxis.

Innovation intensity in Slovakia's enterprises is generally markedly weaker than in the developed EU countries. In small EU enterprises, innovation intensity reaches 5.1 % compared to as little as 3.4 % in the SR. Innovating enterprises in the processing industries in the EU make up 51% whereas only 17% in Slovakia [4]. The links between research and development and the business sector in Slovakia are inadequate, though some technological research centres and business innovation centres were established.

There are many reasons connected with the curriculum changes and with new subjects, trainings supply to students by university. It is clear that also the content, methodology, tools of new subjects have to be suitable and different from traditional form – lectures, seminars, etc. The innovation process of the curriculum of engineering education related to support and development of the entrepreneurial competences of graduates and the steps, milestones and phases of the innovation process are the subject of this paper.

2 THEORETICAL BACKGROUND

The entrepreneurship is based on the processes of discovering, creating, innovating and exploitation [5]. Professor Tom Byers [6] from Stanford University defines technology entrepreneurship as a style of business leadership based on the process of identifying high-potential, technology-intensive business opportunities, gathering resources such as talent and cash, and managing rapid growth using principled, real-time decision-making skills.

The main differences between entrepreneurship and technology entrepreneurship are connected with a great value proposition, technically feasible products, strong intellectual property, a sustainable competitive advantage, a large potential market and a proven business model. It can be based on existing market but also it can be created an entirely new market. The technology entrepreneurship is not only a process in the new independent start-up firms and spin-off firms but also within established corporations and firms.

Garud and Karnoe [7] discuss the technology entrepreneurship basis and state that technology entrepreneurship has several facets including the discovering and creating processes, technological path and knowledge structures. This evokes that it is necessary to support the business or entrepreneurial competences of students and engineers by optional courses included to curriculum.

3 TECHNOLOGY ENTREPRENEURSHIP AND CURRICULUM

The concept of entrepreneurial competences development of students who study the engineering study programmes at the university is based on several principles, e.g. voluntarily, autonomy, interdisciplinary and collaboration. There are used several ways of technology entrepreneurship education, e.g. the optional courses and trainings, creation of cooperation networks, consulting services, workshops and forum of creative ideas, etc. The graduates of the universities of technology are the ones who are expected to know – how to manage working teams, to be active in the areas of research, development, production, marketing, sales, logistics, innovations, finances, etc.

The University of Zilina and Science-technology Park Zilina have developed several opportunities for students with the target to support the technology entrepreneurship spirit. They offer opportunities for students to benefit from experiences and facilities of university and park. The information is also distributed by the webpage http://www.masnapad.sk [9]. There are presented the courses, trainings, discussions, lectures, etc. for example the meetings with the experienced entrepreneurs – best guests, the subjects – Profession: Entrepreneur or Creative Entrepreneur.

The University of Zilina (UNIZA) in cooperation with Science-technology Park Zilina (STP) and Junior Achievement Slovakia (JA Slovakia) has developed the optional experience course for students whose title is Profession: Entrepreneur. Educational programme is based on the model of joint stock-company that represents a good example for all activities and processes of technology entrepreneurship as well as the platform for teamwork. The model illustrates extern and intern firm environment and provides the real experience and the work with real sources including finance. Students as the team members are owners of stocks and they are authorized to sell the stocks to other people for increase the financial sources of their start-ups.

The experience form of the course gives the opportunity to the students to learn from their own mistakes. The course is devoted to the students who want to do something in his/her life; they want to improve and do their best now and do not want to depend on the faculty and study programme. The benefits for students are credits, contacts, friends, experiences and work opportunities.

4 CASE STUDY: MONITORING THE KNOWLEDGE DYNAMICS BY MAPPING THE KNOWLEDGE PROCESSES

To monitor knowledge dynamics it is possible to use qualitative research on case studies and use the methodology of knowledge biography. Their aims are to analyse the knowledge dynamics and connections within the entities and between entities themselves and to understand the complex of events, participants, flows that create knowledge dynamics which is necessary for ensuring change of service or curriculum, etc. The innovation process of engineering education – curriculum and creation and implementation of the new course at the University of Zilina can be illustrated [10] by the two maps of knowledge biography:

- the map of knowledge process at the University of Zilina – milestones of creation, processing, utilization and dissemination of knowledge in the university and in the curriculum. Horizontal division identifies location where the process of creation was realized, processing, utilization and dissemination of internal or external knowledge and a vertical division represents various phases of knowledge process. The time indicated in the map represents different stages of the demands of knowledge process at the university (See Figure 1.)

Phase in the knowledge management process Date of phase completion	Strategic events at the university in relation to the knowledge process – impulses	Decision/making process at the university accompanying knowledge management process	Milestones of application the knowledge management	Entry of external partner in the process of knowledge management
Knowledge creation 09/2008	Creation of knowledge – study about the knowledge and technology transfer process at the UNIZA by UNIZA and STP		New idea prepared for processing – to include technology entrepreneurship to the curriculum	
Knowledge processing 02/2009	Evaluation of course Internal development of idea at the UNIZA	Initiating of the changes of optional courses offer	Elaboration of idea to the information sheet of the optional course	External consulting firm – JA Slovakia
Knowledge using and creation of innovation 06/2009	Supply the course and implementation of processed knowledge into curriculum Curriculum and course approved by scientific and academic boards	Identification of change at the UNIZA and STP – possibilities to supply Planning to further growth, efficiency and provision	Presentation to the students and teachers Optimization of content and methodology Making process changes	Comparison with another solutions (JA Slovakia) Presentation of innovation to the stakeholders at the UNIZA
Transfer and diffusion 06/2010 06/2011	Workshop of possible users and students		Distribution Optimization	New documents, regulations of the curriculum and study programs

Impulses/effects/measurement → Consequences – · → Other processes ······→

FIGURE 1. *Map of the knowledge process at the University of Zilina – milestones of innovation process.*

- the map of innovation process phases at the University of Zilina – represents phases in the process of creation, processing, utilization and dissemination of knowledge throughout the life of knowledge and innovation. It is related to horizontal and vertical fields of the map (See Figure 2).

Phase	Event	Period (month, year)	Localization (country, town, partners)
1. Creation of idea	- participation at the mapping project of the transfer technology and transfer knowledge from the university to praxis - contacts with experts participating at the curriculum development and teachers	January 2008 – September 2008	Slovakia: Zilina, UNIZA, STP
	- creation of the first vision of system's solution of "black box"		Slovakia: Zilina, STP and JA Slovakia
2. Creation of solution	- production of project study, preliminary development	October 2008 – February 2009	Slovakia: Zilina, UNIZA, STP and JA Slovakia
	- development of the first content of new subject and its pilot testing		
	- evaluation of pilot testing - development of comprehensive solution for the summer semester		
3. Further development of product - course	- preparation of the information sheet which presents solution of "black box" as the way of addressing the students and professors to implementation phase - intensive consultation with potential tutors, assistants and professors also with rector/vice-rector and deans	March 2009 – May 2009	Slovakia: Zilina, UNIZA. STP
	- testing new solution - presentation at the university	Year 2009-2010	Slovakia: Zilina, UNIZA. STP
	- further improvement of content and methodology of course	June 2010 – September 2010	
	- further development of "black box"	2011	Slovakia: Zilina, UNIZA. STP

FIGURE 2. *Map of the innovation process phases at the University of Zilina.*

5 CONCLUSION

Based on the knowledge obtained during the preparation of technology entrepreneurship courses and subjects at the university the following conclusions can be reached.

The process of creating, processing, utilization and dissemination of knowledge at the university in the field of education to entrepreneurship and of supporting activities has to be targeted and coordinated. On the realization of the process several institutions take part. Mainly external partners influence the practical part and methodology used in the educational process that requires access, tools and models different from the university and scientific procedures. The approach applied in the technology entrepreneurship cuts across the traditional boundary between the classrooms, home, laboratory and other learning environment. Education to the technology entrepreneurship has to be focused on soft skills, based on connecting the study with practice and creative activities as a part of education (introducing a co-operative education). Students who are ready for practice represent the efficient transfer of knowledge from the university to the business reality.

6 ACKNOWLEDGEMENTS

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254 SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS (STEM) EDUCATION: METHODS TO IMPROVE PSAT SCORES USING A STEM FOCUS

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ABSTRACT

Research has shown that learning experiences in informal educational settings such as camps provide significant benefits for secondary students. In order to expand the amount of students entering into Science, Technology, Engineering and Mathematics (STEM) university majors and ultimately careers in STEM fields, the Aggie STEM Center conducted a two-week summer camp for secondary students (n=35). This study demonstrated the learning successes based on informal PSAT scores that can be achieved through inquiry-based experiences of a STEM summer camp at a major Texas university with inner city high-school students. Results on the PSAT pre/post tests by mathematic, writing, and reading using the 95% confidence intervals indicated that there were statistically significant gains for both reading and writing and less for mathematics.

Keywords: STEM, high school, summer camp, PSAT scores

1 INTRODUCTION/BACKGROUND

In Texas, Science, Technology, Engineering and Mathematics (T-STEM) initiatives offer a fundamental approach to inspiring students, and advancing the studies in these four fields. A key element within the T-STEM initiative are the seven T-STEM centers which are tasked with creating new STEM instructional materials and providing research based, high quality, STEM, professional development opportunities to Texas teachers and students. The Aggie STEM Center is located at a large land-grant university, Texas A&M University, and has research as a central part of the mission. The Aggie STEM Center has extended its mission to work with students as well as educators. In an effort to increase the number of and preparation of students entering into STEM postsecondary studies and careers and to assist in the long-term educational and economic development and alignment of these fields, the Aggie STEM Center hosts an annual summer camp for secondary high-school students.

Originally the PSAT was an acronym for Preliminary Stanford Assessment Test, then Preliminary Scholastic Assessment Test but now it is known just as the PSAT. It is a standardized test administered by the College Board and National Merit Scholarship Corporation in the United States. Approximately 3.5 million students take the PSAT each year in October at their high schools. High-school sophomores and juniors generally take the test but it can be taken as early as seventh grade. The scores from the PSAT are used (with the permission of the student) to determine eligibility and qualification for the National Merit Scholarship Program. The PSAT covers critical reading skills, math problem-solving skills, and writing skills [1].

2 THEORY/LITERATURE

Having informal education (IE) experiences is important. [2] Research shows that IE settings such as camps, clubs, museums, zoos, aquariums and environmental centers provide visitors with active learning experiences that engage individuals in inquiry-based exploration. [3] Based on the work of others [4]-[5], this study provides valuable opportunities for student learning, motivation, and engagement, in learning in a nonthreatening context [6] while fostering positive learning outcomes. The Aggie STEM summer camp design at Texas A&M University shows great promise for fostering inclusive learning across settings. [7]

Research has shown that learning experiences in IE settings provide significant benefits for 12-15 year old children [3]-[5] in two general areas: cognitive and affective domains. [3] In this regard, IEs can yield significant cognitive benefits for children by enhancing their rate of learning and their breadth of conceptual knowledge while also improving their attitudes toward STEM learning. [8]-[9] In particular, females may benefit more from STEM IE because they are given opportunities to take on challenging subject matter without male competition. [9]

STEM interest can be portrayed as a positive inclination toward STEM content areas. When students developed an interest in one of the STEM subjects, this in turn encouraged them to pursue a STEM-related career. [10] Researchers [11] claimed that student's engagement in real-world informal educational activities enhanced students' early interest in STEM. Studies situated in the real world incorporating activities from students' daily lives increased their interest in STEM. [12] Offering additional programs along with schooling experiences helped students consider STEM college majors. [13]

3 METHODOLOGY

During the summer of 2010, The Aggie STEM Center provided a two week-long STEM overnight summer camp for underrepresented secondary students from one urban inner city academy in Texas. These students (n = 35) participated in an intensive STEM focused curriculum for 13 days. Sessions included real world science and math applications through project-based learning (PBL) activities, robotics, university engineering and science lab tours, radio and television communication, museum tours, and PSAT preparation. PSAT preparation sessions were held daily focusing on mathematics, writing, and reading, and for a minimum of one hour. Emphasis was placed on these three content areas plus general test taking strategies. This study demonstrates the learning successes based on informal PSAT scores that can be achieved through inquiry-based experiences of a STEM summer camp at a major Texas university with inner city high-school students. Students were pretested during the first day of camp and posttested during the last day of camp using an Educational Testing Service (ETS) designed assessment instrument.

4 RESULTS

Three regression models were developed (see Table 1), one for each posttest mathematics, writing, and reading, and using the pretest scores as predictor variables. The structure coefficients were computed for each model. The mathematics model was statistically significant (p<.001) with the pretests for writing and mathematics variables being statistically significant predictors. However, the structure coefficients indicated that the pretest score for reading was just as important as the writing pretest for mathematics achievement. The writing model was statistically significant (p=.012). The pretest for writing was the most statistically significant predictor, and the structure coefficients indicated it was the single best predictor. In the final model, reading was statistically significant (p=.03) with pretests for reading and writing being statistically significant predictors. The structure coefficients indicated that preeading was the best predictor followed by prewriting and distantly by premath. Therefore, we can infer from the following that for success on PSAT mathematics both reading and writing are important components. So focusing on mathematics alone without considering both reading and writing will not have as large a gain as a more integrated approach. Success with PSAT writing was not related to either mathematics or reading. However, PSAT reading was dependent on performance in writing, and to a smaller degree on mathematics.

TABLE 1. Regression models predicting outcomes for post test scores in mathematics, writing, and reading.

Model	Independent Variables	r_s*	B	Std. Error	Beta	*T*	*P*	R^2	Adjusted R^2	Model significance
Model 1 (Mathematics)	Constant		3.93	10.39		0.38	.71	**.47**	**.41**	**p < .001**
	Prereading	.125	-0.05	0.14	-0.05	-0.36	.72			
	Prewriting	.078	0.30	0.17	0.24	1.74	.09			
	Premath	.931	0.78	0.17	0.68	4.62	< .001			
Model (Writing)	Constant		23.33	7.50		3.11	.004	**.30**	**.23**	**p = .012**
	Prereading	.464	-0.02	0.10	-0.03	-0.15	.88			
	Prewriting	.984	0.08	0.12	0.11	0.62	.54			
	Premath	.270	0.43	0.13	0.54	3.47	.002			
Model 3 (Reading)	Constant		21.10	9.84		2.15	.04	**.26**	**.19**	**p = 0.03**
	Prereading	.717	0.39	0.14	0.51	2.85	.01			
	Prewriting	.198	-0.12	0.16	-0.14	-0.78	.44			
	Premath	.293	0.35	0.16	0.34	2.16	.04			

Notes. Independent variables for each model is PSAT_post math for Model 1, PSAT_post writing for Model 2, and PSAT_post reading for Model 3.
* r_s = structural coefficients.

When considering pre/post performance by subject, mathematics, writing, and reading, the 95% confidence intervals indicated that there were significant gains for both reading and writing and less for mathematics (see Figure 1).

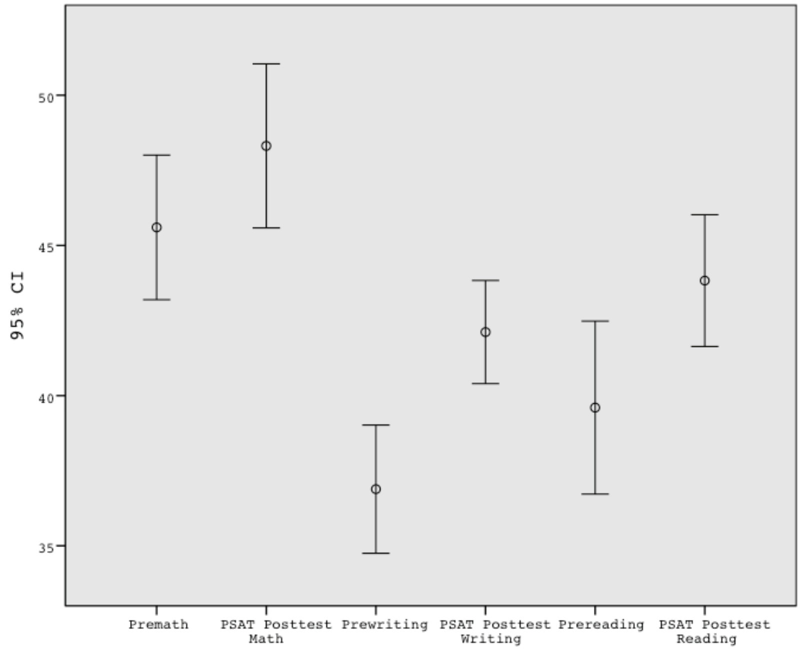

FIGURE 1. *Confidence intervals for PSAT pre/posttests.*

5 DISCUSSION

The results presented above indicate that a two-week long STEM summer camp can result in significant gains in student performance. In addition, even though the camp had a focus in science, technology, engineering, and mathematics, significant gains were made in both writing and reading posttest performance. Increases in scores from pretest to post test were across the board. The most significant posttest gains occurred in writing (the subject with the lowest pretest scores). Reading had the next lowest pretest scores, and also showed significant posttest gains. The highest pretest scores occurred in math, perhaps accounting for the more modest posttest gains. It is possible that a STEM summer camp attracts students with more interest and more skill in math (as evidenced by higher pretest scores).

Based on the experience and data presented above, the Aggie STEM Center is expanding the two week-long STEM summer camp to students from other T-STEM academies. Future camps will include an overnight residential option as well as a day student option for local students (perhaps including middle school students).

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255 A COURSE IN INSTRUMENTATION AUTOMATION

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ABSTRACT

A course in Instrumentation Automation that can be taken by engineering students of all disciplines is described. A programming language called LabVIEW is used in major research and development laboratories around the world, and in teaching laboratories in many universities, especially in the disciplines of electrical and mechanical engineering and physics. The paper describes a course that teaches this language and its application to senior engineering majors. The course is also open to first-year graduate students in electrical and mechanical engineering. Topics covered and samples of projects assigned in collaboration with local industries are explained in detail. With the flexibility of changing the course content, the paper describes the possibility of offering the course at an undergraduate introductory level through the graduate level.

Keywords: Instrumentation Automation, Programming Language

1 INTRODUCTION

Virtual instrumentation applications began in a laboratory and still remain very popular in many kinds of laboratories. Major research and development laboratories around the world, such as, Lawrence Livermore, Argonne, Batelle, Sandia, Jet Propulsion Laboratory, White Sands, and Oak Ridge in the United States, and CERN in Europe employ virtual instrumentation extensively in their work. Of the many programming tools developed for use in virtual instrumentation, the graphical programming language LabVIEW by National Instruments Inc., has been widely adopted throughout industry, academia, and research laboratories as the standard for data acquisition and instrument control software.

LabVIEW, Laboratory Virtual Instrument Engineering Workbench, is a powerful and flexible instrumentation and analysis software system that is can run on multiple platforms and operating systems: Windows, Mac OS X, and Linux, to name a few. It can also be run on PDAs and real-time platforms. LabVIEW programs can also be embedded into FPGA chips and 32-bit microprocessors. It departs from the sequential nature of traditional programming languages and features an easy-to-use graphical programming environment, including all of the tools necessary for data acquisition (DAQ), data analysis, and presentation of results. Such versatility and extensive application prompted the need to offer a course to engineering majors at Wilkes University. This paper describes such an effort.

2 ENGINEERING PROGRAM AT WILKES

Wilkes University is a small, private institution in northeastern Pennsylvania offering programs in arts, sciences, and engineering. The academic units are divided as the College of Arts, Humanities, and Social Sciences, the College of Science and Engineering, the Jay S. Sidhu School of Business and Leadership, and the Nesbitt College of Pharmacy and Nursing. All the engineering programs are housed in the College of Science and Engineering

Degree programs are offered in electrical engineering, mechanical engineering, engineering management, applied science & engineering, and environmental engineering. Most of the courses taken during the first three semesters of study are common to all these programs. The Division of Engineering & Physics (DEP) monitors all these programs with the exception of the environmental engineering program. Thus, students with undeclared engineering major are able to choose a field of study by the end of the third semester. Among the programs offered, the electrical engineering, mechanical engineering, and the environmental engineering programs are accredited by the Accreditation Board for Engineering and Technology (ABET).

2.1 Academic Requirement

The electrical engineering and mechanical engineering degrees require 130 credits to graduate. 25 credits of liberal arts and 24 credits of math and science are included in each program. Courses in computer-aided design and drafting, materials engineering, statics and dynamics, linear systems, computational & statistical analysis, professionalism and ethics, engineering project analysis, electrical circuits and devices, electrical measurements lab, mechatronics, and control systems accounting for about 28 credits are common to both programs. Three credits of capstone courses are taken by both majors during the senior year and they can elect to take six credits of cooperative education, preferably during the junior year. Students get rich work experience in the cooperative education program and practical design experience in the capstone course. Remaining 45 credits are exclusive to each program.

3 INSTRUMENTATION AUTOMATION

The course in Instrumentation Automation is a senior level elective course for both majors. Senior engineering students should have taken courses in circuit analysis, electrical measurements lab, mechatronics, and a programming course using MATLAB and C++ when they elect to take this elective.

3.1 Course Objectives

This course will teach students the fundamental concepts, principle, procedures, and computations used by engineers to analyze, select, specify, design, and maintain modern instrumentation and control systems. Students will gain a sound understanding of the language used to describe modern instrumentation, measurement, and control systems and an appreciation of the various types of systems in common use in industry and research labs. Particular emphasis will be given to electrical signal and thermal measurement systems. The course will also cover statistical tests to evaluate quality of measurements, standard methods of characterizing measurement results, and methods for characterizing measurement system response. The student will experience the following topics: the components of a Virtual Instrument, introduction of LabVIEW and common LabVIEW functions, learn to build simple data acquisition applications, create subroutines in LabVIEW and learn about instrumentation automation through various test interface busses (i.e. GPIB, FireWire, RS-232, etc…)

3.2. Course Outcomes

The course will provide a sound understanding of the important characteristics of a range of modern process sensors, transmitters, and signal conditioning equipment through the use of LabVIEW. At the end of this course, the student should: appreciate the operation of a range of common sensors, appreciate the application of sensors and transducers, be able to design analog signal conditioning circuitry for a range of sensors, appreciate the operation of a data acquisition system and the operation of the main components, be able to design at block level a data acquisition system, be able to select appropriate ADCs, DACs, sample-and-hold amplifiers and other key components, and appreciate some key measurement concepts.

3.3 Topics

In this course students will develop the techniques and skills necessary to design an automated test system and control it using LabVIEW. The topics covered include:

- Introduction to the LabVIEW Application Development Environment
  - o Creating a Virtual Instrument in LabVIEW
  - o Dataflow programming concepts
  - o SubVIs and modular code creation
  - o Data Acquisition in LabVIEW
  - o Loops and Charts
  - o Arrays and File I/O
  - o Waveform Graphs
  - o Strings, Clusters, and Error Handling
  - o Case & Sequence Structures
  - o Formula Nodes
  - o Basic Programming Architectures
- Concepts of data error, measurement uncertainty, data samples and data populations.
- Curve fits, harmonics, frequency spectrum, sampling, and Fourier representations.
- Amplitude, frequency, phase response, system delays, & rise time; 1st and 2nd –order systems.
- Sensors & transducers: Resistive devices; RTDs, thermistors, & thermocouples; variable inductance/reluctance devices; semiconductor devices; & piezoelectric devices.
- Signal conditioning, voltage- and current-sensing circuits, bridge circuits.
- Resonant circuits, impedance matching, A/D and D/A conversion.
- Temperature measurement systems.
- Pressure and force measurement systems.
- Flow measurement systems.

- Fault Coverage, Testability Analysis and Diagnostics
- System modeling techniques

4 PROJECTS

The students are given the opportunity to work on various projects from industry. They are required to develop a project proposal; a one page document indicating the project or topic of in-depth study they have selected. It is to include a title and an abstract, and should reflect serious thought in selecting a meaningful, challenging project related to intelligent automation. The project may be based on research work, drawn from a job experience, or prompted by a journal article. The intent is to provide an opportunity for detailed study into an area of interest that embeds the material of the course. The proposal may explain the student's interest in the topic, and is to include a plan for how the work is to be executed. An example topic would be a plan to develop a dynamic system model and conduct simulation studies of a particular manufacturing system or subsystem that involves sensing, actuation, and control.

A project final report presenting the students findings and in-depth investigation is to be submitted. The report is to follow professional guidelines for technical writing. The reports must be typed in English, and each paper should be approximately five pages in length with figures (with additional support material in appendices).

The report is to contain sections of a technical paper, such as abstract, introduction, background, methodology, results, discussion, conclusions, and references. It should be clearly written with explanations of the system studied, and if appropriate contain derivations of model equations and simulation results. In addition to the report, a presentation of approximately 10-15 minutes in duration is to be made to the class.

Several project topics are presented next.

4.1 Laser Scanner

The goal of this project was to enhance the process of using a Laser Scanner to scan a given object, process the data cloud to remove errors, and then manufacture the part using a CNC machine. Along with reducing errors of the scanned image, reducing the time it takes for the scanning process and image processing is the main component of this project. Automation was incorporated to improve scanning accuracy. 3D Image processing was used to remove imperfections in the scanned object. Automation of the laser scanner allows the whole object to be scanned with minimal overlap. This was accomplished using four motors, which were able to move the scanner in the x, y, and z directions, with no human interaction needed, other than to turn on the scanner and run the LabVIEW VI, all of the human error is eliminated. Figure 1 shows the front panel of a laser scanner.

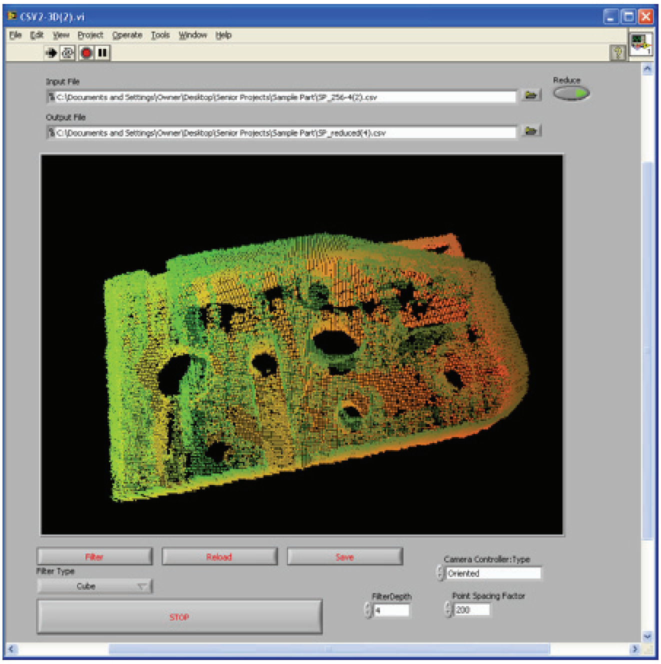

FIGURE 1. *LabVIEW Laser Scanner Front Panel.*

4.2 Canard Deflection Angle Measurement System

This project developed the automated test system design for the Canard Deflection Angle Measurement System for the Pneumatic Control Assembly. The most critical requirement being that the system performs a non-contact measurement of the canard pneumatic assembly. The new test system was implemented using a vision system. Several digital image processing techniques were used to insure that the new measurement technique is reliable and repeatable. All code was developed in LabVIEW and used the NI-IMAQ IEEE-1394 driver to develop the image processing algorithms, validate the developed algorithms on a preproduction model, and overcome the challenges listed to create a reliable and maintainable test system.

The LabVIEW VI calculates the rotation angle for each frame of the video. The video file contains the frame rate. This will be used to plot rotation angle versus time. This will be used to calculate rise-time and fall-time. Rise-time is the time required for the canard socket to rotate from trail to 90% of full deflection. Fall- time is the time required for the canard socket to rotate back from full deflection to trail 10% of full deflection. The VI will also measure the maximum deflection angle and minimum deflection angle. Figure 2 shows the VI graphical user interface.

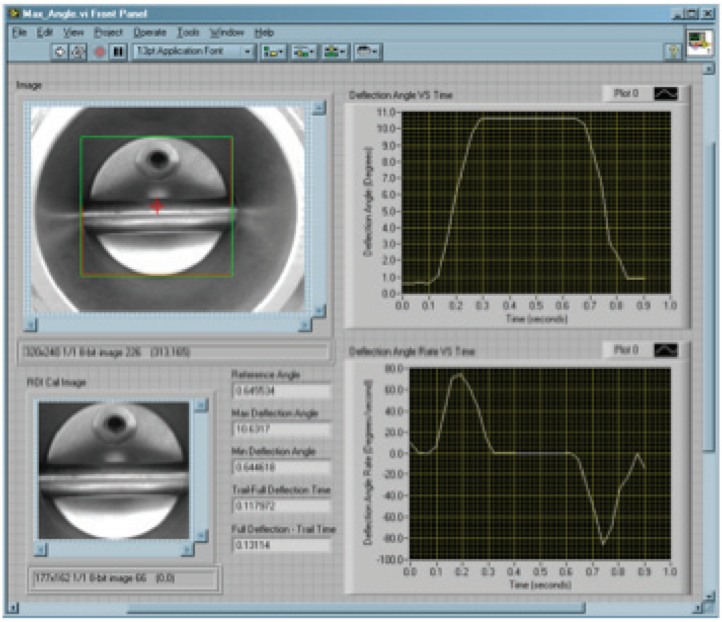

FIGURE 2. *VI Graphical User Interface.*

4.3 Wavetek 154 Emulation

This project developed an emulator to replace the obsolete Wavetek 154 function generator with the Agilent 53220 function generator. The Wavetek 154 is controlled through a custom binary coded decimal (BCD) interface. The student had to use LabVIEW and a digital I/O module to read the BCD bus and convert them to commands in the IEEE-488 bus for control of the Agilent 53220 function generator. A BCD bus signal generator was developed and was used to test the Wavetek 154 Emulator. The BCD emulator provided control of the Wavetek 154 using a LabVIEW program. A program was developed to read the BCD bus and output commands using an IEEE-488, GPIB card to the Agilent waveform generator. The BCD emulator was used to test the project.

4.4 Seizure Detection Though Adaptive Filtering of Electroencephalogram Signals

The purpose of this project was to design an adaptive digital signal processing (DSP) filter to remove the noise component in an electroencephalogram (EEG) signal. The signal was analyzed to help detect the onset of a seizure. This detection could be used to command a vagal nerve stimulator to fire and stimulate the vagal nerve and stop the seizure. This system was not intended to predict future seizures. It was an endeavour to identify the onset of a seizure. All DSP algorithms were developed using LabVIEW. The system will receive brain wave activity input from electrodes placed on the scalp of the patient and electrically amplify and filter the signal. An ARM7 processor with a built-in analog-to-digital converter will sample, digitize, filter, and characterize the brain wave. The digitized waveform will be used to determine when seizure brain activity is occurring.

This project concentrated on the EEG signal analysis. EEG data was captured and processed in LabVIEW. As part of the project the EEG signal was read and the signal was presented in time and frequency domains. An adaptive filter was designed. As part of this project the student did an examination of adaptive filtering, filter design, and the final filter's amplitude and phase response. An analysis of the filter's effectiveness was discussed and the filtered data examined in both time and frequency domains. Finally, the filtered EEG signal was analyzed to identify when a seizure occurs. The code was downloaded to the ARM7 processor for execution. Figure 3 shows an unfiltered spectrogram output from LabVIEW.

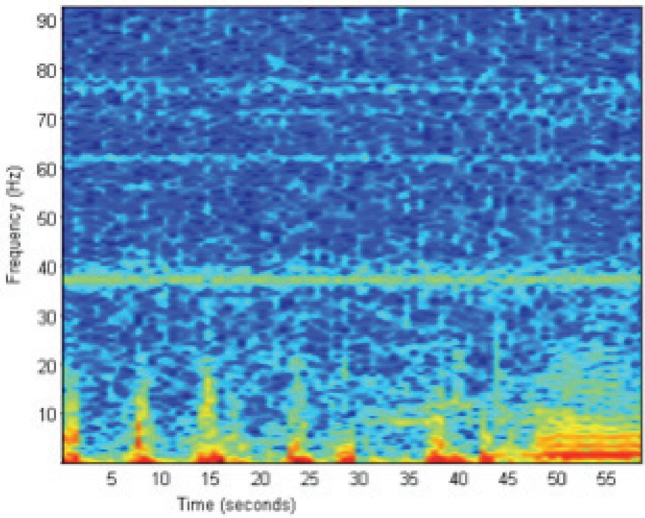

FIGURE 3. *Unfiltered EEG Spectrogram output from LabVIEW.*

5 CONCLUSION

A course in Instrumentation Automation that relies heavily on a programming language called LabVIEW was presented. The course can be taken by engineering students of all disciplines. The language is especially useful in the disciplines of electrical and mechanical engineering. The course described is offered at the senior level at Wilkes University for engineering majors. In addition the course is open to first-year graduate students in electrical and mechanical engineering. The students are presented a wide range of instrumentation automation topics in preparation for industry driven projects. Students who have taken this class have been successful in finding employment in companies, such as, Lockheed Martin, Instrumentation Engineering, US Department of Defense, Fairchild Semiconductor, and many more.

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256 HOW TO PROMOTE INNOVATIONS THROUGH APPLIED RESEARCH IN COLLABORATION WITH SMES?

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ABSTRACT

In this paper, we present a model how innovations and innovation capability can be promoted through applied research which is carried out in collaboration with small and medium enterprises and an applied research group. The CENTRIA model integrates applied research and education. It is based on technology expertise, technological capability and business knowledge with collaboration involving the enterprises, the research personnel and educational personnel. The model emphasizes to proactively take into account the needs of current and future customers. We will present our experiences gathered in collaborative applied research projects between the enterprises and CENTRIA. The research approach has been found beneficial both sides: innovation capability has increased remarkably in both partners. The collaborative applied research projects have produced tens of new business opportunities and many of them have already been used in the enterprises. The academic research activities with field experiments have given the research organization tools for publicity, respect and cooperation possibilities on an international level. The developed model is planned to be extended to wider user in Finland in the future.

Keywords: SMEs, applied research, innovation

1 INTRODUCTION

European Union has great challenges to become the Innovation Union until 2020 which has been set as a goal in EU strategies. The gap between visions and current status is worrying especially when considering small and medium enterprises (SMEs). The bureaucratic framework programs are currently forming the basis of European innovation strategies but they are often too complex for SMEs. On the other hand, SMEs have great potential both in regional and global innovation systems. In order to sustain the increased competitive pressure, innovation is considered as being the most valuable sources of growth and competitiveness for the SMEs [1]. However, the strategic knowledge necessary for innovation not only concerns technology but also business intelligence, funding, marketing and other non-technical areas [2]. Technology transfer and SME-oriented applied research should be complemented with collaborative creation of new business opportunities.

2 PROMOTING INNOVATION CAPABILITIES OF SMES

Innovation capability and innovativeness are important for SMEs to survive and create competitive advantages. However, the innovation processes in SMEs are often neither efficient nor systematic, which makes the innovation cycle from ideas to market slow [1]. It is important to remember that innovation is a two-edged sword as Chesbrough [3] described it: "Most innovations fail. And companies that don´t innovate die." Prahalad and Krishnan [4] stated recently that there is an ongoing transformation of business. It will alter the nature of the firm and how it creates value, and it is forged by digitization, ubiquitous connectivity, convergence of technologies and industries, and globalization. According to Prahalad and Krishnan no industry is immune to these trends that cannot be reversed. These trends also create competitiveness challenges to SMEs around the world.

An important part of innovation processes is the capability to fully utilize the latest technology and capability to innovate. Innovation capability is defined as the holistic, corporate-wide potential of a company to generate new and unique values [1]. Innovation capability can also be defined as the skills and knowledge needed to effectively absorb, master, and improve existing technologies, and to create new ones [5]. The task of innovation capability can be focused on developing new products and to adapt the whole enterprise to the changing environment [6]. Measuring and evaluating innovation capabilities or innovativeness of SMEs has been found a hard task. The central problem in measuring innovativeness or innovative capability is that these are not directly observable or identifiable. Innovation capability evaluation tools are often quite specific in nature, and they are mainly based on quite straightforward statistical analyses of questionnaires or surveys. Some of innovation capability measurements presented in the literature use the number of patents as one indicator for the innovativeness of the firm. However, the expense and effort needed in the patent pending process is often beyond the SMEs capability. This lack of activity does not mean that these SMEs are not innovative; they may have a lot of innovative solutions in their development projects. Therefore, also indirect measures have been developed for innovative capability evaluation [1, 6].

The active and continuous cooperation of the research team and SMEs is crucial for the success in promoting innovations. The means involved are those which Sarasvathy and Venkataraman recently proposed as the mechanisms for their entrepreneurial method: action, interaction, reaction, transformation and explicit co-creation [7]. Research organizations should help this process in a spirit which Wong defines as a collaborative culture [8]. It is characterized by being empowering, supportive, trusting, unifying and professional. The helping relationship attitude proposed by Schein [9] has also been found important inside the applied research team. As Schein argues, this helping process is dynamic, and it includes building of trust, cooperation, collaboration, teamwork, leadership, and change management. Members of applied research teams should also learn team play in the helping spirit and this should be extended to collaboration with firms and other R&D units.

3 COLLABORATION OF SMES AND THE CENTRIA'S TEAM

The CENTRIA model is based on integration of technology expertise, technological capability and business knowledge with co-creation involving the enterprises and the applied research group [10]. The typical development cycle in collaboration projects with SMEs has been carried out through the following six phases, which are partly overlapping and they may sometimes be iterative.

1. Analyzing the needs of the SMEs
2. Technology development monitoring
3. Learning and developing advanced technology based methods
4. Planning pilot projects or technology demonstrations together with the SMEs
5. Implementing the pilot projects or technology demonstrations
6. Evaluating the business opportunities of the developed solutions

Analysis about the needs of the SMEs starts from humble inquiry [9] and proceeds to questionnaires and interviews. Technology development and status of automation are monitored from several sources including continuous follow-up of conferences and publications, analysis of statistics, future trends and roadmaps, and visits to conferences, exhibitions, universities and companies. In the third phase CENTRIA's research team learn how to use the most advanced technology found in phase 2. After that, the research team starts to adapt or develop novel methods suitable for the local SMEs. This is necessary because many advanced technology solutions found in the world have been designed for large companies and cannot be directly implemented for the SMEs. The fourth phase is planning the pilot projects or technology demonstrations together with the SMEs. In the fifth phase the plans are implemented either in the SME production facilities or in CENTRIA laboratories. Often these demonstrations lead to further development work, either directly by SMEs or together with the research unit and suppliers. The final phase evaluates the business potentials for SMEs, the stages of practical implementation, technology development needed by suppliers or research, and the increase of competence needed in SMEs.

The innovation focus in the CENTRIA model is not limited to product innovations but it is extended to consider also service, process, marketing and organizatorial innovations and their proactive combinations as presented in Figure 1. Proactive refers to preparing expected and unexpected changes in the future; e.g. product innovations take into account the future process changes such as RFID-based identifying of products also in smaller shops or factories or the increasing spread of mobile phone based payments, or utilization of social networks for marketing products or services. However, proactive combination innovations have to fulfill the Drucker's classic requirement: "Don't innovate for the future. Innovate for the present!" [11]. This means that these innovations should be ready to be taken into use, but following the open innovation principles [3] they are designed so that they can confront the future change of social practices introduced by disruptive innovations. This may also require continuous reinventing of strategy in some high technology areas which are developing fast. Proactive Combination Innovations can also cover the future needs of SMEs' customers; these needs may be currently unclear for customers. Collaboration projects involving research groups and SMEs can also bring about proactive combination innovations to fulfill the future technological needs for

SMEs, which they have not yet encountered or are not prepared to face. Proactive combination innovations will in the future be more and more cross-disciplinary in nature.

FIGURE 1. *Proactive combination innovation and its relations to other innovations.*

More than fifty companies have participated in collaboration projects with CENTRIA, and the companies have been mainly production-oriented SMEs. The applied research projects have been conducted in the areas of robotics, simulation and wireless automation. The collaborative projects have produced new business opportunities and collaboration has enhanced the innovation capability of both SMEs and the applied research group. The evaluation of business opportunities showed that many of them were assessed to have good or excellent business potential, and several innovations have already been used in the production of SMEs [10]. Figure 2 shows an example of the evaluation how SME innovation capability has developed in robotics and simulation technologies during the collaboration of SMEs and CENTRIA in the latest decade [10].

SMEs have extended their collaboration networks from suppliers and customers to include networking with R&D units. SME innovation capability has developed most in the areas of robot programming, virtual modeling and simulation, and digital competitiveness.

According to the experiences of CENTRIA applied research group, creating of collaboration culture between SMEs and an applied research group takes time. The main factor to enhance innovation capability in the SMEs and small research groups is the development of collaboration culture [8], which is based on integration of co-creation [7], trust and helping relationship [9] with technology expertise, technological capability and business knowledge, which should proactively embrace the needs of current and future customers. In fact, experiences of this study verify Schein's [9] arguments that only team players with a mutual helping attitude will succeed year after year in development groups.

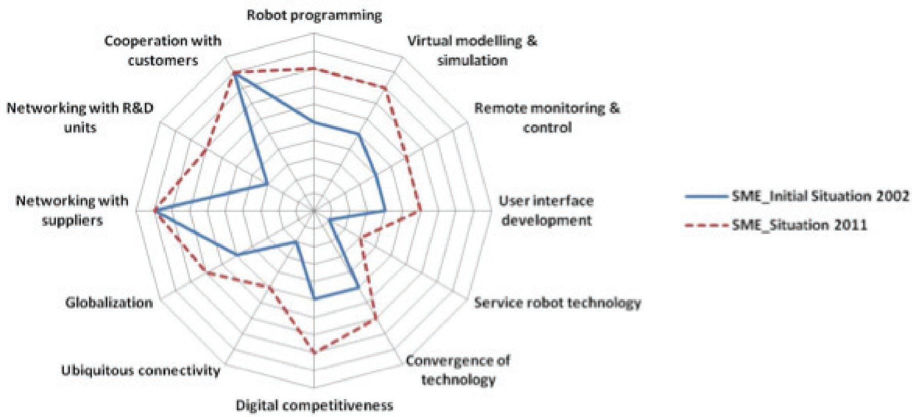

FIGURE 2. *Development of SME innovation capability in robotics and simulation technologies during collaboration of SMEs and CENTRIA.*

4 INTEGRATION OF APPLIED RESEARCH AND EDUCATION

The R&D work in universities of applied sciences should be integrated to educational processes. The expertise of teachers of professional subjects in the universities of applied sciences is based on both their theoretical studies and work experience. They are considered as teachers and experts at the same time. Just theoretical expertise is not sufficient but the teacher should also have practical experience and know-how for implementations. In the CENTRIA model this has been assured by sharing the working time of education personnel both in teaching duties and SME-oriented R&D tasks. Working time divisions vary typically from 20% to 80%. The active working in two different tasks has been found successful because teachers can develop their expertise in projects. Teachers typically have limited resources to develop themselves if they have only teaching duties. This is often problematic in professional subjects that require continuous learning and training of the most advanced equipment and software.

The integration of educational and R&D tasks has been visualized in Figure 3. The dashed area where educational and project personnel are overlapping is the core element of successful integration of applied research and education. Even if educational personnel interact with enterprises only by visits and final theses, they have had no time to concentrate on the needs of enterprises. On the other hand, if project personnel are not at all involved in educational tasks, their information about the most advanced equipment, methods and software tools is not transferring to the students. Project-based learning plays central role in the educational processes of the CENTRIA model. The interaction of project and educational personnel brings real-life project topics for students and it can also be utilized in focused visits to companies. Sometimes students can be employed in projects as project assistants or they can find jobs in collaborating enterprises. Typical implementation of robotics courses currently includes following subjects: lectures in advanced learning environment, visits to robotized production in companies, literature-based textual exercises, robot simulation exercises, and robot programming exercises in laboratory using industrial robots, mobile robots, 3D measurement devices and machine vision.

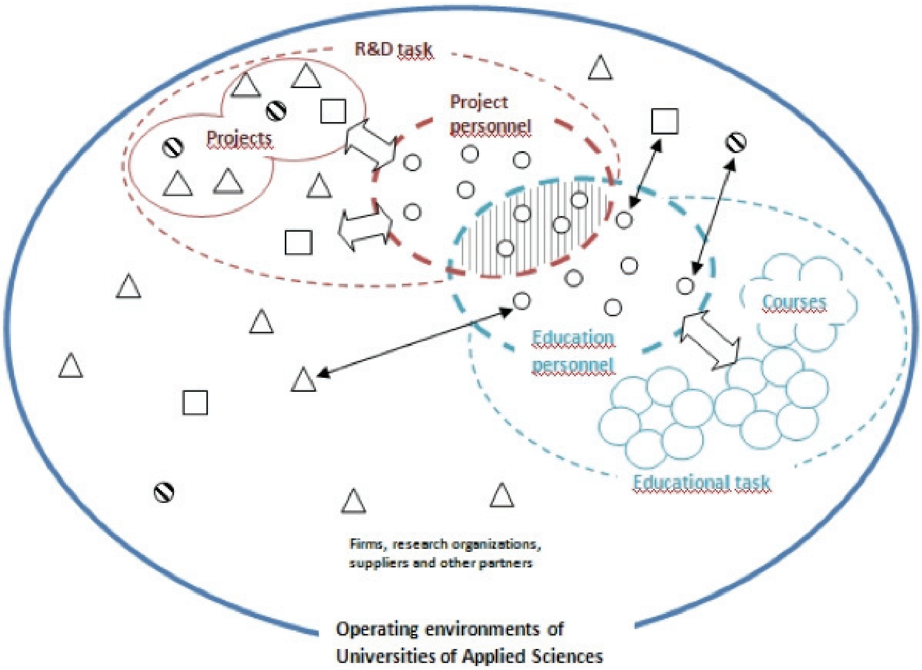

FIGURE 3. *The integration of educational and R&D tasks.*

5 DISSEMINATION POSSIBILITIES FOR THE MODEL

In the upcoming academic year, we have planned to study how the CENTRIA model could be extended to wider use in Finland together with other educational organizations. In this interaction, the best practices will also be included to the next version of the model. When comparing the practices used in CENTRIA with the CDIO (Conceiving – Designing – Implementing – Operating) standards [12], it can be stated that most of the implementation models in CENTRIA have been carried out in spirit of CDIO. Working in teams, active learning by doing and using blended learning are examples of methods that fulfill the CDIO standards. Turku University of Applied Sciences (later Turku UAS) has been developing CDIO adaptation several years [13] and it will offer a good platform to integrate the best practices of Turku UAS and CENTRIA. Therefore, the first application area is planned to be the game development education. Game Development will be one of the specialization areas from autumn 2012 in the B.Eng. Degree Program in Information Technology (later IT program) of Turku UAS.

Several courses in the IT program rely currently on the problem-based learning (PBL) implementation. For example, the first semester course in Product Development has reported to have been successful [13]. In Game Development specialization area, PBL implementations will cover courses such as Study Skills, Basics of Science, Introduction to Game Development, Capstone project, and Game Development 1-2. Especially, Capstone project will be one of the most potential courses to exchange experiences between CENTRIA and Turku UAS. This course will be piloted in upcoming academic year for whole faculty (including totally five curriculums). Capstone projects will be organized based on Capstone Initiative in which the main idea is to collect experiences in industry based projects [14]. Also ICT ShowRoom event, in which students are organizing an exhibition and a competition open to all students, will be one another possible implementation to be analyzed because it is gathering every year students, staff and industrial representative together [13]. Figure 4 illustrates how the CENTRIA model will have influences to PBL implementation in Turku UAS in the upcoming academic year.

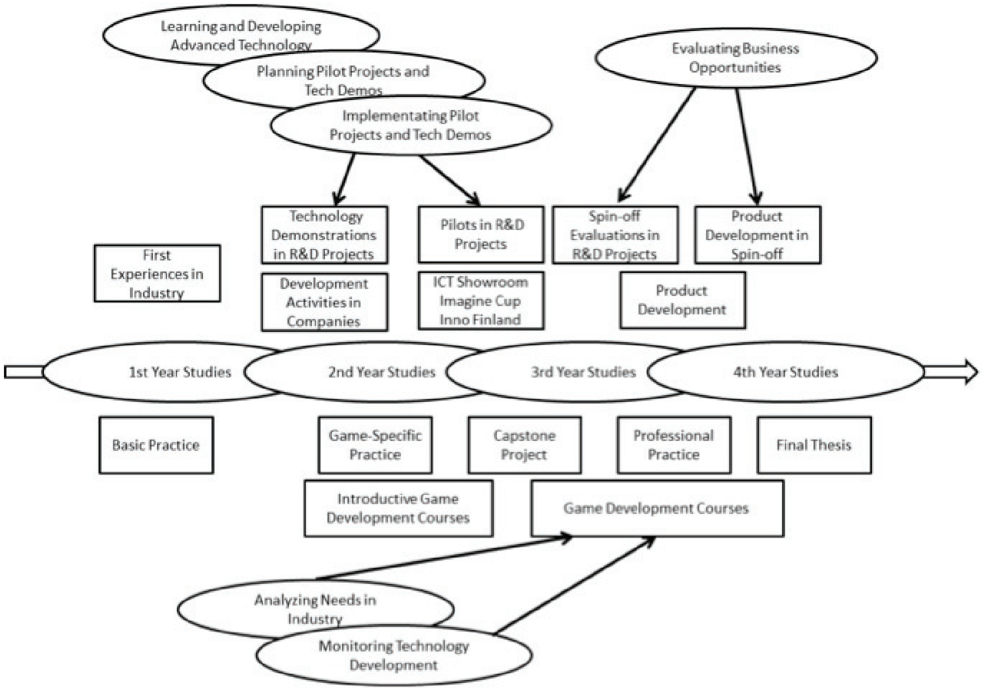

FIGURE 4. *The integration plans of CENTRIA model and PBL implementations in Turku UAS.*

6 CONCLUSIONS

We have presented the CENTRIA model for integrating applied research and education in collaboration with enterprises and especially SMEs. The results have been encouraging: innovation capability has increased remarkably both in SMEs and in applied research group of CENTRIA and it has also had positive effects to CENTRIA's educational processes. We have started to disseminate the model in cooperation with Turku UAS and we are optimistic that it will find new applications in the game development education, research and development.

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261 ENGINEERING THE SCIENCE AND ENGINEERING EDUCATION

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ABSTRACT

Engineering education has often been a topic of discussion in universities, resulting in the modification of engineering courses and curriculums to teach and learn more about real-world problems. These modifications include the accommodation of multidisciplinary topics, the reduction of the number of hours in math, science and engineering courses so the average student can complete an engineering degree in four years time, and taking advantage of fast growing and easily accessible information technology. This has often been done in most schools on an ad hoc basis and not as a carefully designed process, often resulting in curriculum and course changes that actually produce less qualified scientists and engineers. In particular, the inclusion of information technology may have resulted in a generation of graduated professionals with a good level of information, but not a sufficient level of fundamental knowledge to go hand-in-hand with the acquired information. Normally, it is expected that the pros and cons of using information technology are carefully addressed in science and engineering education before actually being integrated into courses and curriculums. In this paper, an attempt is made to present the advantages of using engineering based education models for science and engineering education by using examples of already successful programs and principles of "engineering the science and engineering education."

Keywords: Information technology, knowledge, learning environment.

1 INTRODUCTION

Today's engineering education is facing considerable challenges on how to effectively make use of available information and translate that into usable knowledge for students and professionals [1]. Deficiencies [2] in engineering education have been addressed often in university committees, publications, and proposals to find suggested solutions. The expectation is normally to teach or learn more about real-world engineering design, cover more and up-to-date areas of engineering, have better communication skills, be adaptable to future changes, have critical thinking skills, be able to connect between technology and society, and much more [3]. It is often expected to reduce the number of hours in math, science, and engineering courses so the average student can complete an engineering degree in four years time.

This paper is not a result of specific study in a particular school, but a result of many years of experience in research and science and engineering education, working through many different forms of curriculum and observing successful and not so successful science and engineering programs. One particular observation is the impact of the explosion in information technology

(IT), which provides easy access to answers of most (if not all for undergraduate students) engineering questions. This makes it easier to search for a solution of a problem rather than think or work the problem through. This is actually true for both students and instructors. In other words, individuals will most often have information about, but not true knowledge of a given subject. This may help the aspects of covering more up-to-date materials, but have a negative impact on the adaptability and critical thinking parts of engineering education.

1.1 Objective

To solve an engineering problem, a person will go through the process of definition, modelling, design, optimization, implementation, testing, and quality control before the work is actually completed. This process may differ for different fields of science and engineering in each step (and may require more or less steps) [4], [5]; however, the structure for a successful outcome of each is conceptually the same, as is the expectation for a quality engineering education program. A successful engineering education program is also the result of a carefully modelled process that defines clear paths for students from start to end. The purpose of this paper is to suggest and discuss engineering approaches to science and engineering education, as have been conceptually followed to solve engineering problems.

2 BACKGROUND INFORMATION

In the Massachusetts School of Law's presentation of Educational Forums, 2007, comments were made from the chairman of the Electrical Engineering Department at Stanford University (SU), indicating that: ". . .the finest university in the world, in the world, preparing electrical engineers, undergraduates, is Sharif University in Technology . . . ." However, in the overall ranking, Sharif University of Technology (SUT) does not even place in top 300 in the world. Yet, SUT's undergraduate program in electrical engineering is considered to produce the finest electrical engineering graduates in the world. It is also true that the top graduates from SUT follow their graduate degrees, often with fellowships, at universities such as the Massachusetts Institute of Technology (MIT), SU and other similar institutions. The question is, why are undergraduate electrical engineering students at SUT so successful?

2.1 Engineering approach, example 1

The conceptual process of preparing students for top schools, like SUT, starts at the high school level. First, students choose the field of their interest when they enter high school, such as art and literature, science, or math. The top students in science are likely to choose medicine or related fields, while the top students in math will end up as engineers. This process has recently been changed and the selection category modified to also allow vocational, technical or academic fields. Second, for students to enter a university, they must take a national exam. Statistically, it has been shown that only the top .1% of overall students taking the national exams may be accepted to enter schools like SUT to pursue an electrical engineering degree. Third, after entering into SUT, the students will select one of four areas of interest: Electronics, Power, Control, or Communication. Fourth, the students stay in the program and follow a structured curriculum step by step. In addition, the essential engineering courses are all designed and integrated to complete the path of knowledge that is expected from electrical engineering students who graduate from SUT. The success rate of these students becoming graduates is above 95%.

Clearly, this is not a model that is used or can necessarily be used in the United States and many other universities worldwide, nor is it the best model that takes advantage of current and improving information technology. However, knowing about the success of such a program provides useful information, worthy of consideration as a process for “engineering science and engineering education.”

2.2 Engineering approach, example 2

Another good example that seems to be engineered for success is the process of receiving a medical degree in the United States and many other places in the world. Generally, a student has already shown some level of academic success, by having an undergraduate degree with a good grade point average, and also having some specific and selected courses in their background. This is relatively equivalent to the high school degree example that is presented in the previous section. The student must also pass a required exam (MCAT) with an acceptable grade, similar to the national exam also shown above. With the two in place, the interested student then applies to the medical school of his or her choice and if sufficient, they will be called for an interview to be examined for suitability of the student for that specific school, on a competitive basis.

Accepted medical students enter into academic work that is already structured for two years for all students in the program alike. Success or failure of the student in the program is dependent on the student’s ability and dedication. Recent data from the National Resident Matching Program, April 2012, indicates a 95% success rate for the student to achieve residency.

A medical degree program is structured and the process of selection and preparation of students is carefully engineered. The program is also modelled, designed, and implemented for success. One notable aspect of medical education is the fact that all students in the program must follow a rigid curriculum at assigned periods, thus knowledge from one subject to the next follows according to a specific model, already engineered.

2.3 Information Technology, example 3

The use of information technology in today’s science and engineering education is a reality. Academic professionals, the general public, and particularly students will use IT since it is available, easy to use, attractive, and most often helpful to a student’s learning, if used properly. The question is how to manage the use of IT to benefit science and engineering education when helpful, and discourage the use of it otherwise. As an example, consider the following simple computer science/engineering problem, asking students to implement a digital logic problem, in an attempt for students to learn a particular concept and use critical thinking to solve the problem.

An n-bit ripple adder is made from n one-bit full adder building block as shown below in Figure 1.

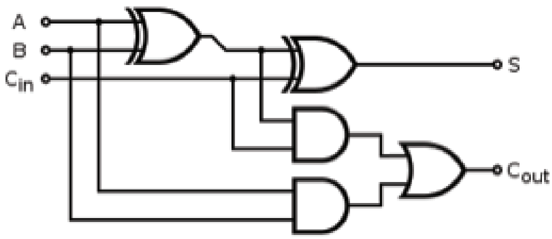

FIGURE 1. *A one bit full adder to provide information for solving a specific problem.*

By connecting the C_{out} of the lower significant bit to the C_{in} of the next higher bit, the n-bit ripple adder will be realized. In this design, except for the building block of the lowest significant bit, all other building blocks must wait until the C_{out} from the previous building block is available to be completed. The time required for the n-bit ripple adder is at least n times the required time to complete a one bit full adder. As shown in the schematic, the C_{out} function is:

$$C_{out} = (A \cdot B) + (C_{in} \cdot (A \oplus B))$$

An alternative to the ripple adder is to design a system that can have C_{in} for all one-bit adders available at the same time, thus the system operates faster. This is called a Carry Look-ahead Adder (CLA). The students are asked to use the above formula and drive functions for all C_{in}s (except for the first C_0, already provided as input to the system) and design a 4-bit CLA.

The students can easily find an answer to the problem, shown in Figure 2, on-line and present that answer, also believing that by having the solution they also captured the knowledge for it. The fact is that the purpose of such questions is to encourage students to use critical thinking and work the problem through. This way students will understand the solution for each C_{in} at the algorithm level before realizing the functions at the digital logic level, thus practicing an important concept of Boolean function processes, which is a fundamental part of learning computer system design.

The question can appear more complicated to students who try to learn the concepts by going through the solution, Figure 2. The solution would be simpler understood once the students work the problem through by driving the necessary Boolean functions from C_{out}, Figure 1.

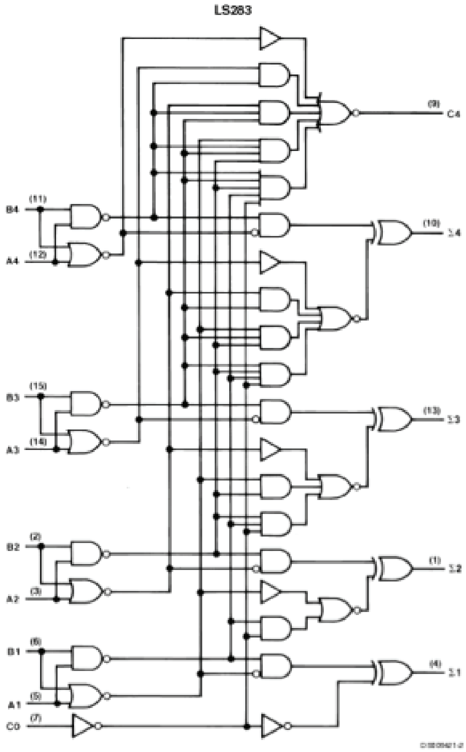

FIGURE 2. *A 4-bit CLA schematic; the final solution to the question asked.*

Having the final solution readily and easily available creates a challenging situation for educators and education programs in general. The requirements for dealing with such challenges for a successful program may often appear to be as simple as making an ad hoc decision on the part of the instructor (making the instructor responsible), to be more rigid, etc. The fact is such problems are more fundamental and broad based within the curriculum requirements, topics in each subject, and the methodology of handling the topics in each subject among science and engineering programs. This situation is expected to become more challenging, as expectations for use of IT become more demanding.

3 DISCUSSION/METHODOLOGY

With the many complex and diverse requirements of todays engineering education, having carefully guided paths that can evolve as the requirements of science and engineering education advances are essential. Important issues to consider include requirements for multidisciplinary education, expectation for inclusion of topics to deal with real world problems, and the expectation of inclusion of IT in education, to name a few.

The fact remains that any detailed model that focuses on one specific issue independently (ad-hoc), while working for some time for selected degree programs, may also create new issues requiring new revisions of other parts of the curriculum soon after. For example including real-world or multi-disciplinary topics to the curriculum may result in cutting down on essential topics of science and engineering. This often results in a watered-down solution, sometimes by making use of IT for the purpose of keeping the degree program within limited academic credit requirements. The fact also remains that education programs such as those explained in sections 2.1 and 2.2 continue to be successful in their outcomes since they follow a well-defined path for achieving the goals of their degree programs. Globally, the key issues in science and engineering education should follow a consistent path. The top-level key issues can be summarized as:

a. Outcome: The intended engineering approach should clearly define the goals of each specific program, may that be conventional electrical engineering programs, multi-disciplinary biomedical engineering, or computing and informatics, etc. It should define what would be expected from the graduate students from such programs from the start while keeping the requirements and impact of IT in mind.

b. Selection: One very important factor of a successful program as explained in section 2.1 and 2.2 is the selection process. Depending on the complexity level of each particular program, the selection process is quite essential. Often we have seen that intelligent students with a good level of knowledge have failed a low-level academic program, while similar students will succeed very well in a much more challenging program. Often, placement tests could be a correct approach to start entering students into the appropriate level of course work.

c. Topics: The selection of required subjects in science and engineering programs are becoming more complicated since, as science and technology evolves, the desire for adding more topics in the curriculum increases while the number of required credit hours does not. This may only work to a certain degree if the program is inefficient to begin with. The key factor is to keep the expected outcome in mind, while adding and subtracting courses from the curriculum. Modeling a curriculum after current successful programs is a good place to start, while allowing some space to add technical electives and outside concentration to the program, and without compromising the essential and required topics for each particular degree.

d. Areas: The contents and areas of coverage in each fundamental topic are as essential and critical to a successful science and engineering program as the top three listed above. The key issue to remember is the connectivity of contents from one course to another. It is critical to keep the integrity of essential contents in each course intact since students often change programs from one institution to another. This is why the example in 2.3 must be taken seriously to ensure that students acquire the necessary knowledge, not just acquire information. Sometimes, depending on the topic, it may become necessary to create learning environments such as laboratory settings and group activities to achieve this objective.

e. Diversity: Todays science and engineering education often demands inclusion of multi-disciplinary knowledge in its curriculum. The importance of this issue is two-fold. On one hand, the selection of fundamental topics should not be compromised. On the other hand, the selection of diverse topics should be somehow related and complementary while it is in another disciplines. Conventionally, breadth and/or outside concentrations have been used to bring diversity into a specific curriculum.

Clearly, the above is far from a proposed solution, but an attempt to open a dialog discussion for improvement of broad-based science and engineering education that can evolve.

4 CONCLUSION

Todays engineering education is highly multi-disciplinary that can: benefit from including diverse knowledge of other disciplines; benefit from international exposure that is modelled after successful engineering programs (even with programs with minimum technological, informational, and financial capabilities as shown in section 2.1); benefit from fast growing IT if integrated and modelled properly to complement traditional teaching.

In the background section three cases are presented: 2.1 showed one successful engineering program in a middle-eastern country; 2.2 presented that the success of most medical school graduates in the United States benefit from a defined structure, which can be considered an engineered process; 2.3 showed that while IT can be extremity useful in providing essential information for science and engineering education, it can also be abused and have a negative impact on learning, by using the information only as an answer and not as a learning environment opportunity to acquire knowledge.

Neither example presented in 2.1 and 2.2 are clear enough evidence to define a solid methodology for science and engineering education; they are just examples of successful educational models. However, they could be used to open up a path for discussion and planning processes to consider an engineering approach to engineering education; to make the best use of old ways of engineering education – already practiced in some of the best schools in the world – combined with the vast amount and ease of using information through IT to address the complex requirements of engineering education.

In Section 4 a methodology for "engineering the science and engineering education" is discussed resulting in introducing five essential key issues. Each of these points – Outcome, Selection, Topics, Areas, and Diversity (OSTAD) – are significantly important to bring about a path toward successful science and engineering education for now and many years to come. Much of these steps, if not all, have been practiced in the same way at many top schools in the world with successful outcomes. OSTAD or other such models will become a useful tool through continuous dialog discussion in meetings, educational workshops, symposiums, and discussion among groups of science and engineering schools, which may result in improving science and engineering education.

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263 ENGINEERING STUDENTS INVOLVED IN ACTIVITIES TO MOTIVATE HIGH SCHOOL STUDENTS FOR ENGINEERING COURSES

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ABSTRACT

This work refers to the project Lab InCognITA - Laboratory of Innovation in Cognition, Information, Technology and Learning - under development at the São Paulo State University – UNESP, Brazil. The project aims to motivate High School Students for the Earth Sciences and Engineering Careers. To achieve its objectives, it includes activities for both Students and Teachers from the High Schools taking part in the project. The activities for the students involve essentially the accomplishment of "Energy Shows" and of "Energy Exhibitions". The activities for the teachers involve the realization of training courses, having as its main focus "Energy and Environment" and as a pragmatical approach the project-based learning methodology. The shows are related to the subject of "lecture demonstrations". In the shows, undergraduate students from the Earth Science and Engineering Courses of UNESP conduct a presentation making use of several devices, aiming at illustrating the Physics Principles. In this article, we claim that students participating in the project activities, not only can help High School students to become more motivated for the Engineering careers, as also contribute to their own formation, as the developed activities help them to fix contents of specific subject matters of their courses.

Keywords: Science Teaching, Lecture Demonstrations, Engineering Education, Energy.

1 INTRODUCTION

The "Lab Incognita - Innovation Lab in Cognition, Information, Technology and Learning" aims essentially to promote the development of a set of activities and projects with high schools, seeking to arouse the interest of students to the areas of technology and engineering. The activities are being developed in the context of an agreement established between the UNESP and FINEP - Studies and Projects Funding Agency, with the consent of the Government of the State of São Paulo (Grant No. 01.08.0386.00, Reference No. 5017/06). The project was approved under the Public Call: MCT / FINEP / FNDCT - PROMOVE - Engineering in High School 05/2006, which had as its main objective: "to select proposals for funding innovative projects that promote greater interaction among the engineering schools and the teaching activities of natural sciences and mid-level in order to awaken vocations and recruit more and better students to technological areas". For the purpose of the call, it was understood as exact and natural sciences: Mathematics, Physics Chemistry, Biology and Informatics. The activities developed in the Project have as their catalyst theme "Energy and Environment". In this sense, the project provides activities for both the students (energy shows and exhibitions, among others) and teachers (teacher training and the development of teaching projects).

The methodology being used in the project is the Project-Based Learning - PBL, constituting one of the topics of teacher training programs developed in the project. The activities and projects should emphasize the major current technological issues, seeking to establish connections with the fundamental knowledge of the exact and natural sciences such as mathematics, physics and chemistry. The main purpose of this project is to support teachers in dealing with subjects of science and technology in the classroom and to arouse the interest of students for careers in technology. Project activities may involve the development of experiments and models, and use of software that would enable teachers and high school students to appropriate knowledge regarding the issues discussed.

The development of shows and exhibitions has been done by students of engineering who work in the project as scholarship holders. These students not only take responsibility for presenting and explaining to visitors and the general public, the scientific concepts involved in each experiment demonstration as well as take care of the maintenance of the devices required in the shows and presentations.

The involvement of scholarship students with exhibitions and shows, performed in the project, was such that it caught our attention to the role these activities played in motivating those students to continue studies in engineering. In this study, we evaluated the impact of activities undertaken by scholars about the motivation in their studies related to engineering courses.

2 MOTIVATION, LEARNING AND SELF-DETERMINATION

Studies on motivation for learning constitute a major focus of concern of educational research, as it may indicate the level of involvement of students with educational activities proposed by the teacher inside and outside the classroom, as also propose solutions in order to extend the dedication of students around the tasks proposed [1].

For Vygotsky [2], learning necessarily involves social interaction processes in which human beings construct their understanding of the world around them from the other mediated relations. That is, our understanding of things is established from the provision of meaning by the relationships established in the cultural environment in which we live. In this sense, there is an intimate relationship between cognition and culture.

Vygotsky [2] also draws attention to the fact that logical thinking is influenced by our emotions. On this view, the author points out that every thought or idea is generated by needs and desires that motivate and sustain our actions. Thus, one can understand that triggered emotional relationships and social interactions, in turn, keep close relationships with the cultural environment of which we are part, and are essential to the learning process. So from that perspective, we can conclude that, for the author, the motivation is fundamental to the learning process, bearing in mind that, ultimately, student involvement depends on this energy that keeps him or her focused on activities for education proposals.

To Bzuneck [3], one can define motivation as a process that causes the students to adopt a behavior that enhances the level of interest and curiosity necessary to involve them in the tasks proposed by the teacher, by providing the means to overcome obstacles that arise. Ryan and Deci [4] demonstrate the existence of two types of motivation: extrinsic and intrinsic.

While extrinsic motivation is a process triggered by factors outside the individual, intrinsic motivation is generated by internal mechanisms, ie, while extrinsic motivation moves the individual from external pressures such as environmental aspects. There is an intrinsic motivation natural tendency of the individual to seek new challenges, in order to test its capabilities. Thus, intrinsic motivation can be considered as the process that best represents human potential for growth and psychological integrity, because in addition to being spontaneous, it is autotelic.

In this sense, learning activities should be based on strategies that are able to provide the triggering of the motivational process, guaranteeing student self-determination in overcoming the demands required by the learning process. However, as highlighted by Guimarães [1], most often, schools fail to develop educational activities that go beyond traditional forms of teaching that do not generate the motivation necessary for the proper involvement of students.

Andersen et al. [5] argue that studies related to Self-Determination Theory have been used as a basis for developing strategies for the development of motivational processes. According to the authors, the Theory of Self-Determination is based on the idea of the existence of basic psychological needs and man's innate need, that, when met, create a sense of well-being. They highlight three basic psychological and innate needs to be satisfied to generate intrinsic motivation: the need for autonomy, the need for competence and the need to belong.

Guimarães [1] explains that the need for autonomy is related to the perspective that people are more likely to engage in activities because they believe that they conduct of their own accord, or they have originated as having internal causality. The contrast indicates that people tend to avoid performing activities for which they feel pressured to perform externally.

Regarding the need for competence, the author highlights the fact that the individual needs to relate well with the environment in which he or she is inserted. In this sense, the experience of achieving a challenging task generates a "feeling of efficacy" that produces an acknowledgement of people around him or her. The positive emotions generated by the acknowledgement of the social group to which we belong strengthen the feeling that we are able to perform new tasks increasingly complex. When this need is not met there is a feeling of insecurity that deters the individual to face new tasks.

Finally, the third basic and innate psychological need, according to the Theory of Self-Determination which should be satisfied to generate the necessary motivation for the individual to face new challenges is the need to belong.

For Guimarães [1], the need for belonging is related to the human beings tendency to link up with people emotionally significant social group to which they belong. Thus, every human being has the need to maintain enduring interpersonal relationships. When this need is not met a person is frustrated and has compromised the emotional balance. From this point of view, pedagogical design of teaching strategies, potentially motivational, should be capable of providing an environment that fosters students with a view to satisfying these three basic psychological needs.

In this research, we intended to assess how the activities in the project Lab InCognITA contributed to the development of an environment capable of meeting the basic psychological needs of engineering students, scholarships holders of the project, in order to motivate them to their study area.

3 RESEARCH

The main objective of our research was to understand the role of the activities undertaken by scholars, students of engineering, in the context of a project whose aim is to motivate high school students to pursue a career in engineering. For this we rely on the prospect Theory of Self-determination to understand the processes that triggered the motivation in scholarship holder students in their studies on engineering and dedication to the work proposed in the project.

Students participating in our research are scholars in the project "Lab Incognita - Innovation Lab in Cognition, Information, Technology and Learning" - whose main objective is, through a series of activities with high schools, attract the interest of students to areas of technology and engineering.

3.1 Methodology of data analysis

The scholarship holder students, from the engineering courses, answered a semi-structured questionnaire, with open-like questions, on the activities they performed in the context of the project, from which we analysed how the actions taken by the students led the satisfaction of basic psychological needs that justify the involvement of each of them not only in conducting the activities as well as in their studies on engineering.

The questionnaire, consisting of seven open questions, aimed at understanding how students viewed the way they were proposed and carried out activities under the project, and how they felt about the independence, skills development and sense of belonging in relation to the group working on the project and in relation to students and high school teachers. In addition, some of the proposed questions sought to understand how participation in the project has changed their relationship with the engineering course.

3.2 Data Analysis Methodology

The answers given by students were analysed from the indication of whether, in carrying out activities related to the project or not, there was the satisfaction of basic psychological needs of each student.

Our aim was to identify which of the project activities contribute to the increase the motivation of the student to study engineering.

4 RESULTS AND DISCUSSION

From the answers presented by the students in the questionnaire it was possible to perceive the existence of intrinsic motivation to perform activities related to the project, in view of evidence that the basic psychological needs included in the Theory of Self-Determination were satisfied.

The first sign observed here is with regard to the need for autonomy. All scholarship students said they feel autonomous in the performance of their work on the project. It is clear that both the show and the exhibition feature a presentation template and a roadmap to be followed. However, students feel free to provide feedback, suggest innovations and propose modifications to this structure, given that many of them are accepted, or at least taken into account by the group. We must consider that, for autonomy, we are not saying that it should be "do what you want", ie an authorized practice of laissez-faire. The project has a policy, objectives to be achieved and a well defined methodology. However, it encourages the development of initiative, creativity and autonomy of the participating students.

The speech of one of the students in the survey clearly shows this fact:

> *"The scheme of the project scheme is inflexible with regard to the show and the exhibition itself, because the experiences, schools, the timetable and methodology are already pre-defined. But the fellow has the autonomy to lay out the presentations, to innovate with regard to the explanations to propose new ideas".*

In this sense, as all are encouraged to present their ideas, suggestions and intentions, it is important that each group member is able to interact with each other in order to argue and persuade on their own initiative. This, in our view, contributes to the development of the ability of students to work in teams, imposing them the challenge of having representation in that social group.

From this perspective, there is a basic psychological need satisfaction on the skill. By participating in an innovative group and that leaves room for implementation of the ideas presented by its members, each member is challenged to make suggestions, criticisms and positions that collaborate with the improvement of the project development.

In one of his responses a student calls attention to the fact that the project creates a challenge with regard to competence:

> *"The participation in the project encourages people to study more, know the basics, laws and concepts relating to Science: Physics and Chemistry. In addition, stimulates people to be more communicative, to interact more with people in order to understand them and be understood".*

We must emphasize that this sense of competence stems from the fact that the students feel recognized by college roommates:

> *"I feel important before my colleagues because my participation in this project takes me apart from other students".*

From the point of view of competence, the scholars feel challenged not only by the project members, but also by teachers and high school students for whom they carry out the exhibitions and shows:

> *"I feel challenged to better understand the phenomena that are treated in the experiment that we performed so that I can better explain to the students for whom the project is presented. Not only for students, their teachers are there watching too".*

This feeling of being challenged can also be observed in the speech of another scholarship who calls attention to the importance of doing everything right to highlight the name of the institution to which she belongs:

> *"I feel very motivated to do the best, to give opinions, suggestions. And all that I think that needs to be modified, I inform for the good of the project. I think that in this way I help in the development and recognition of FEG-UNESP".*

This comment illustrates also another psychological need met in the activities developed in the project: that of belonging. In the speaking of the scholarship it may be noted that it demonstrates the pride and feeling for/of being a student from the FEG-UNESP.

In our view much of the desire of the students to participate in activities related to the project is related to the pride feeling of being recognized as belonging to the FEG-UNESP. This need for belonging and satisfaction on account of participation in the project can be seen in the following statements of one of the scholars:

> *"My participation in the project makes me feel important before my colleagues, because I develop an interesting and important project".*

> *"I do not feel superior to my colleagues, but I feel important, because many would like to participate in this project".*

Some students' statements show the relationship between participation and motivation of the project for learning in courses aimed at teaching engineering subjects:

> *"I think my participation in the project helps me to better understand the basic concepts of physics, chemistry that are important to engineering".*

> *"My participation in the project made me more communicative and less shy. This allowed me to be more interactive with my peers and teachers. That helped me a lot in learning".*

> *"Understanding the experiments involves not only understanding the scientific concepts, but the conception, construction and operation principles of the equipment. I think it has everything to do with engineering".*

These last speeches of the students really relate to the indications of Vygotsky's theory. Scholars point to the importance of the project to contribute to greater social interaction with peers and teachers and to cultural matters related to engineering. Social interaction and culture provide students with an informal education, ie, one that provides a complement to formal lessons of the great subjects of the curriculum of engineering courses. They promote extra-class experiences through dialogues, readings, or cultural experiences, important to the development of their learning.

5 CONCLUSIONS

The results of the research draw attention to the importance of motivation of students in engineering education to a more meaningful learning. The traditional teaching methodologies, typically experienced in the classroom, have not proven to be sufficient to motivate students to engage closely with the matters raised in their subject matters.

Of course, the lists of exercises, tests and works are important to get students involved in extra-class activities. However, this engagement is not made spontaneously, and thus is only driven extrinsically. The qualitative results of our study emphasize the importance of intrinsic processes to the students' learning.

6 ACKNOWLEDGEMENTS

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269 INTEGRATING INNOVATION ACTIVITIES IN AN MASTER LEVEL CAPSTONE PROJECT COURSE

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ABSTRACT

The computer engineering and computer science curricula at Åbo Akademi University have had for more than 10 years a capstone course, called Project Course, where student teams implement larger software or combine software/hardware systems. A major change in the education environment was in year 2006, when information systems students, a business curriculum, was integrated in the department. At that point, activities for integrating innovation were added to the course development. The aim of the innovation activities is to try to make the students aware of their possibilities, as well as to encourage them to form start-ups based on either ideas in the Project Course or to further develop their ideas. To this point, year 2012, at least two companies have been formed based on the technical work done during the Project Course. In parallel, a student entrepreneurship organization has been formed in the university campus area, which today is a major, student based, co-operator to the Project Course. This paper brings forward the development of the Project Course and the supporting activities around it. We explain the cooperative work and how it affects the students in the project work during the course.

Keywords: entrepreneurship, course curriculum, IT education, student projects

1 INTRODUCTION

For a long time, innovation has been a buzzword in the western world. With the decline of traditional large industries in Finland, such as forest industry, shipyards and even relatively new telecommunication industry, there is political demand for new innovation-driven industries, expected to contribute to the growth needed for the society. Already ten years ago, Castells and Himanen [1] stressed that innovation and the need for building entrepreneurialism among the young are key challenges in the Finnish society. Since then, this need has only grown.

In order to start the discussion we need to define what we mean by innovation. Firstly, an innovation is something that is not directly (logically) derivable from the well known knowledge around us. An innovation must be an artifact that breaks the normal way of thinking. Secondly, an innovation must be something that generates value, i.e. it brings value to the users or the environment around it. This value might not always be something that people are willing to pay for, but it should provide a change to its surroundings. For instance, a new physical model explaining some phenomena, based on vast amounts of basic research is not necessarily an innovation; the innovation is only when we find a way to use the model to provide value to the society. This also leads to some basic learning outcomes for education that should support innovation. The education process should explore what innovation is, how it is achieved and measured.

Today, the general trend in technical education is to promote innovation. The most visible example in Finland is the joining of the three separate universities in capital Helsinki area to form the Aalto University. Three different disciplines of education were joined for one main reason: to be a cradle for innovation. But as such, only doing an administrative join of universities does not help: corresponding activities are needed. Just as an example of such an activity is the forming of a new educational program called Service Design and Engineering (SDE), which is discussed in [2]. On European level, the European Institute of Innovation & Technology (EIT), which recently started its operation, has innovation as its key element.

We, as a rather small university, cannot of course by our own change so much. But we can for sure do small changes at grass root level, and let that change slowly grow. In this paper, we are explaining how innovation driving activities have been included, through a Project Course, in the curriculum of the study programs at the Department of Information Technologies at Åbo Akademi University (IT/AAU). We show what kind of activities have been included, at which stage, and we analyze how well they support the goal that our students will be innovative now and in their future careers. We also analyze to what kind of growing these activities have contributed so far.

The Project Course is not unique as a capstone course. It appears for instance, in the curricula of Aalto University [3] and at Tampere University [4]. However, we promote a certain structure in our Project Course and address the need for student motivation; we believe these key features have made this course a favorite among students. We proceed as follows. In Section 2, we describe the setting of the Project Course at Åbo Akademi University. In Section 3, we discuss how the innovation driving activities are integrated in our course. In Section 4, we analyze the impact of the course structure and its main activities on the students.

2 BACKGROUND – SETTING THE SCENE

The Project Course at the IT/AAU is a graduate-level course, recommended among the last courses a student attends in a Master-level curriculum. The goal of the Project Course is for the students to develop a software-intensive system by working in a team. There is a very limited amount of traditional teaching in this course; instead, the students are provided with the opportunity of applying earlier gained knowledge when developing a product that is significantly more complex than a typical academic assignment. This type of course has existed at our department for at least 15 years; however, a major change occurred when the department was reorganized.

In 2006, the former Department of Computer Science was replaced by the actual Department of Information Technologies with three disciplines: Computer Engineering (CE), Computer Science (CS), and Information Systems (IS). CE is an engineering programme focusing on software engineering and embedded computing. The CS programme consists of computing and programming methodologies with a focus on abstract reasoning as well as interdisciplinarity.

The IS programme offers a strong business component in addition to various studies on managing software-intensive systems development.

Once the department was reorganized, the focus of the Project Course also extended correspondingly to the change. While earlier the Project Course students were required to demonstrate (only) programming and documenting skills, currently the students need to also develop a business/exploitation plan. Each team is encouraged to have students from all three disciplines.

Most importantly, the course culminates with the ICT Showroom event, a public competition held at the ground floor of our university building. All the projects must be completed by and demonstrated at the event. A jury appointed from industry selects the best project. The members of the winning project get a significant prize (in 2012, each student of the winning team received a brand new Nokia Lumia phone).

In the 2012 edition of the ICT Showroom event, 56 projects were presented; 47 student projects and 9 research projects. The student teams represented the 3 universities in the Turku area: Åbo Akademi, University of Turku, and Turku University of Applied Sciences. 11 of the student projects were projects developed during the Project Course. In total, over 200 participants have been present in the event. Such an event provides both a positive pressure and a motivation for the students during the course.

FIGURE 1. *ICT Showroom 2012.*

The objective of the Project Course is to plan, design, implement and deliver a software product in a team. The team creates a specification of the product, often with the help of an external customer; creates a project plan, designs a solution, and implements the solution. The project should be carried out within the strict time limit of seven months. Students are evaluated during the execution of the project based on several deliverables and presentations they produce. A team consists of four to six students. The idea of the project is either provided by the course lecturers or by the team members. There are two main requirements to pass the course:

1. A working product/demonstrator at the end of the project. The team has to deliver a running system, together with documentation, source code, and a test suite.
2. A business/exploitation plan detailing why and how the solution is useful and/or how it can be turned into a viable business.

Each team is assigned a team mentor, one of the lecturers in the course. The team should have about four meetings (or more, if needed) with the mentor as the chairperson. The mentor supports the team on managerial issues, such as helping with setting up the organization of the project, with prioritizing and finding the right activities needed for going forward. The Project Manager can contact the mentor if s/he feels any need for support in organizing the work of the team.

Each project has an external customer, i.e. a person not part of the development team. In most cases, the customer will be a professional working in the software industry. The team will interview the customer to create a product vision, define the main product requirements and validate these requirements with the customer. The students own the intellectual property created in this course.

This course corresponds to 10 ECTS points and has no written examination. Instead, the team creates and delivers on time a number of deliverables. The students are graded from 1 to 5, based on active participation in lectures, presentations, project implementation and project deliverables. The course includes 3 evaluations:

- First evaluation after setting up the team, worth 10% of the grade
- Second evaluation upon presenting a prototype, worth 30% of the grade
- Third evaluation at the end of the course, worth 60% of the grade

There are several aspects with respect to the impact of this course on students, their innovation potential and the Finnish society. We describe these aspects in more detail in the following section. One obvious characteristic of this course is that it provides an environment for working life experience: each group has a project leader, a client (external stakeholder), and a mentor (one of the teachers). In fact, this is the most often provided feedback from the students: "this was the first and only course where I felt I was doing something real".

3 THE INNOVATION PROCESS

The Project Course provides an innovation framework intended to foster the innovation capabilities of the students in a guided (yet constraint free) environment. The "guided" environment basically imposes a strict format for the course phases, milestones, and deliverables so that the students do not have to focus on practical details and just be creative. The latter implies that the students are encouraged to decide for themselves how each phase is approached, and how the deliverables are produced and shared within the team. At the end of each phase the students will present during a lecture some aspects related to the project, such as status, idea, plan, etc. In addition, each milestone has a list of deliverables that should be provided by each project team. The milestones provide both a target for the students and a checkpoint for the lecturers. In fact, previous research has shown that running similar project courses without a guided framework results in learning project management by mistakes.

Our approach is different from the "typical" university course in which the course lecturer "dictates" the activities of the students throughout the course. Another difference resides in the fact that, compared to traditional courses in which students are basically accumulating theoretical knowledge, in the Project Course the students have the opportunity to combine and apply in practice the theoretical knowledge obtained in the previous courses.

During the Project Course, students have the opportunity to learn practical project management in teams. Also they are responsible for planning and executing the projects, for taking decisions and allocating resources accordingly. In fact, this course is also intended to familiarize students with real-life working situations which they will face once they graduate.

The phases of the Project Course are based on the milestones depicted in Figure 2. For each milestone the student team has to present in a lecture the current status of the project, milestone specific information, and deliver the corresponding deliverables. In the following, we will briefly go through the main phases of the Project Course.

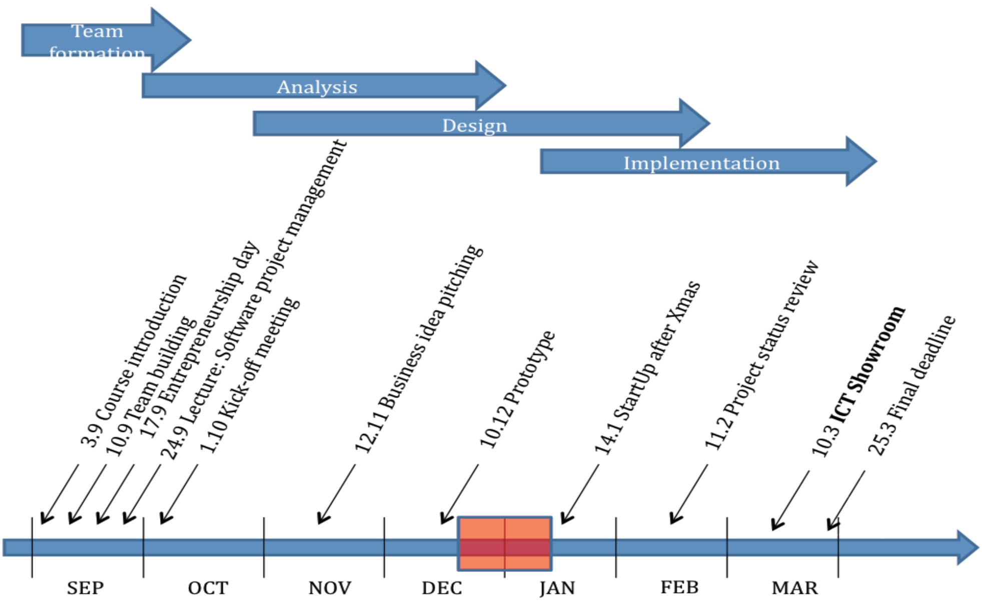

FIGURE 2. *Example schedule of the Project Course, edition 2011-2012.*

Course introduction. The rules and settings of the course are introduced to students, followed by the presentation of project ideas by the external customers. Students have the liberty of suggesting their own project idea. The only requirement is that the final product will be related to the information technology field and that the effort required is compatible with the duration of the Project Course and the size of project team. Being able to select a project of their choice and on their favorite topic increases the motivation and dedication of the students. For projects suggested by students, one of the lecturers will act as a customer.

Team formation. In this phase, project teams of 4-6 students are being formed. The students are responsible themselves for forming a team by eliciting either their own project idea (previously discussed with and approved by the lecturers) or their skills (developer, designer, project manager, analyst, business analyst, etc.). As the students participating in the course belong to the three complementary directions at the department, we encourage the teams to have members from all three directions.

The students in this course are at master level (years 4 and 5 of study) and they are both local and foreign students from countries inside and outside EU. For instance, in the previous version of the course around 40% of the participants have been foreign students coming from 9 different countries. During the team formation phase we also encourage the students to form multicultural teams, with members from at least two countries. The students have 2 weeks for forming the teams and agreeing on their project idea, team members and the duties of each member.

Analysis Phase. In the analysis phase each project team analyzes and decides the features of their product based on the discussions with the customer, on estimations regarding the effort required to implement the product. A project plan is also created in which the team details the team members, roles, tasks of the project, schedule and allocation of effort.

In addition, each team has to prepare a business pitch presentation in which they pitch the idea of their product in four slides – four minutes. The point of the business idea pitching is to make the team think about the core idea of the project and how to commercialize it. The pitch is evaluated by an external panel. The panel includes business-oriented professionals, as well as members from Boost Turku, a student entrepreneurship organization whose mission is to provide guidance on creating new start-up companies among university students. The analysis phase ends with the presentation of a product prototype by each project team.

Design and Implementation Phases. During this phase the project team has to decide the architectural design of their product, by making an internal review of different design options. The implementation phase is mostly about implementing the design decisions taken in the previous phase. At the end of the implementation phase a functional product should be demonstrated in the ICT Showroom event. During both phases, the project teams are encouraged to choose their favourite or to explore new technological solutions, especially solutions that they consider that will give their product a competitive advantage.

ICT Showroom. The ICT Showroom (described in Section 2) represents the main milestone of each project. In addition, it has been observed to be the main motivating factor for our students. During this showroom, each team will have to demonstrate their final product to a wide audience, including students, lecturers and public. Each project team will get a stand, a poster panel and the necessary equipment for their presentation. They are free to decide on how to market and advertise their product to the public via posters and marketing materials. An external jury is evaluating all projects at the event; the evaluation criteria are for instance, degree of innovation, technical content, and overall presentation.

Wrap up phase. After the project presentations in the ICT showroom, in the wrap-up phase, each project team delivers the technical documentation, user manual, and the source code of the product. In addition, a post mortem analysis presentation is given, in which each student team presents to the other teams and to the lecturers, a post mortem analysis of their project. This analysis includes things that went well during the project, things that went wrong, as well as lessons learnt by each team.

3.1 Skills and competences acquired

The course is not only a practical course in software project work, but also a means to develop skills relevant for innovation. Among this we mention: interaction with the customer, communication requirements and design decisions, planning and developing a software project. The students also learn how to review the plan during the execution of the project, reflect over their initial expectations and estimations, how to work in a team and how to present their project, product, plans and documents.

4 RETROSPECTIVE

The group development model presented in [2] suggests that a working group or team develops in four stages: forming, storming, norming and performing. The forming stage is a comfortable stage in which the group gets to know each other and agrees on goals and tasks. Storming is the next stage, where different opinions are expressed and conflicts between team members occur. This is a critical and important stage to pass in order to move on with the task. The norming stage is when the team is solving their interpersonal issues and the members make personal sacrifices in order for the team to work towards a common goal. When the team reaches the performing stage, the team structure and roles are clear, the work is done smoothly and members are motivated. Our experience is that the teams in our course also pass through these stages. However, we believe that most of the innovation occurs during the norming phase, when the team realizes that good ideas are not enough, but they have to be packaged into a complete solution that satisfies both technical and business re quirements. The ICT Showroom provides the motivator for evolving from basic ideas to innovation.

The team dynamics in our course are very different due to the different cultural and technical backgrounds of the students from one year to another. In many occasions, some students in a team already know each other from previous courses and have already gone through the stages of group development. Some teams are built from scratch from students with different backgrounds and some subgroups need to form new teams with new students of various backgrounds.

Over the years we have worked out a course structure that will guide the teams in their development process. Having this structure (detailed in the previous section) with clear steps in forming the teams and producing deliverables, forces the students to learn how work together and how to collaborate for achieving the final goal. All the presentations in class and the definite deadlines force the teams to work and perform. In addition, a mentor (lecturer) is assigned to each team. The role of the mentor is to be there in case the team runs into difficulties and to make sure that the project is making progress.

Supporting entrepreneurial activities in the university teaching is encouraged in Finland. As explained above our aim in the course is to lower the barriers for starting a company and to think about the business potential of the developed solution. We are proud to say that we have two interesting companies that started out from an idea developed during the course. These former students of ours are invited to the course to give a short speach about how the coursework has contributed to their success. In the feedback given from the students we can also see that the work done to actually develop a product that someone would find useful is much appreciated.

5 CONCLUSION

In this paper, we put forward the Project Course at Åbo Akademi University, with an emphasis on activities driving innovation. The main observation is that having a well structured course format helps the student on working on the contents, instead of dealing with practical issues. Activities that force them to be able to formulate their vision and ideas, understandable to other persons, drive innovation. For the overall motivation, a final presentation, visible for the public and the jury, is essential. The complete package gives a good basis for student innovation, which is proved by very interesting and challenging projects, into which the students put a lot of effort.

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270 WORLDWIDE-ACCESSIBLE 1.25 GBPS ADVANCED LASER COMMUNICATION LABORATORY

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ABSTRACT

Novel information technologies have had a profound effect on engineering education. Leading American universities provide global access to their theoretical courses via the Internet; however, this highly beneficial development does not offer the laboratory component crucial for quality engineering and science education. Our efforts address the inherent limitation of all Internet-based educational technologies by creating an infrastructure that provides remote access to advanced instrumentation. Unlike virtual laboratories, the proposed technology brings real hardware to the fingertips of students, thus facilitating the development of important experiences. It features a fully operational laser communication link installed on the Binghamton University campus between two buildings separated by one-kilometer distance. The link provides a basis for a Worldwide-Accessible High Performance Experimental Laser Communication Laboratory that offers its state-of-the-art instrumentation and educational technology for conducting pre-designed and open-ended experiments in the areas of digital communications, physics and electro-optics to the international community of engineering students. Combined with the Internet-based delivery of theoretical courses, it can fully satisfy requirements of both graduate and undergraduate engineering education across national and social borders.

Keywords: Engineering Laboratory, Internet, Remote Experiments.

1 INTRODUCTION

The amounts of knowledge expected at the baccalaureate and master's levels show drastic increase. Fortunately, the on-going revolution in information technology results in innovations in university education that can address these requirements. The system of engineering education is especially receptive to evolution of the Internet, global communication systems, computers, etc. However, there is one area in engineering education that is still dominated by classical teaching/learning methodology: the laboratory. This can be easily explained: the purpose of an engineering laboratory course is to teach future engineers to interact with the "real hardware" in all its complexity and imperfection. Any attempt to replace the "real hardware" in a student laboratory with the most elaborate simulation software can result in the loss of realism and prevents students from gaining important practical skills and experiences. Unfortunately, modern engineering laboratory equipment is highly expensive, requires expensive maintenance and repair, which along with the floor space requirements often exceed resources of many universities. This justifies the existence of laboratories utilizing virtual reality techniques: virtual reality is better than no reality at all.

The technology presented in this paper is not a virtual reality laboratory. It is a hardware / software infrastructure providing remote access to advanced instrumentation via the Internet. Developed under the National Science Foundation's funding, it brings real hardware to the fingertips of students, thus facilitating the development of important skills. All aspects of operation of this hardware are controlled by a designated computer through a number of actuators and extensive monitoring, data acquisition, and mishandling mitigation systems. This system has been upgraded to achieve global accessibility via the Internet, thus allowing remote users worldwide to perform any experiments in real-time and collect response data representing properties of the actual devices. The choice of the specific technology, laser communication, reflects the interests of several engineering disciplines, such as communication, electro optics, physics, electronics and controls.

Speaking of more general aspects of engineering education, we realize that although the same textbooks are utilized by most engineering programs, the variability of quality of education is often caused by the accessibility of advanced laboratory environment. While instructional television and the Internet already deliver theoretical courses worldwide, Internet-accessible laboratories can match this ability by delivering high quality laboratory courses developed in the most advanced universities. These advancements have the potential for strengthening engineering programs all over the world thus offering high quality engineering education to diverse groups of population well beyond national, social and geographical borders. The novel educational technology described in this paper can be instrumental in addressing this issue.

2 LABORATORY COURSES IN ENGINEERING EDUCATION

Laboratory courses constitute a very important component of engineering education. Authorities in the area of methodology of engineering education emphasize the role of student laboratory in achieving such educational goals as "experimental skills," "sense of real world," "taste of discovery," "understanding equipment," "motivation," "appreciation of the power of team work," "networking skills," "communication skills," and "the importance of independent learning," see [1], [2], [3], [4], and [5]. Indeed, only in a laboratory course can students design, implement, and later assess a plan of an experiment leading to the solution of the formulated problem, that includes development of an experimental setup, choosing a rational sequence of stimuli, recording, analyzing and interpreting data. Student laboratories provide a demonstration of the power of proverbial "poor contacts", second-order effects, hidden dynamics, measurement noise, effects of overheating, cross-talk between wires, etc. A well-designed laboratory experiment presents students with uncertainty, non-trivial outcomes, and an opportunity for discovering new, not mentioned in a textbook, properties and phenomena. It is said that complex engineering systems and instruments, being sensitive to many hidden environmental effects, "live their own lives", and the ability to understand equipment is a long, sometimes life-long, process that starts in a student laboratory. Only the experience of a specialist can overcome Murphy's Law, measurement noise, unexpected behaviour of hardware, etc. and obtain the needed results from the available equipment under existing conditions. Unlike theoretical problems reflecting only the simplified quantitative side of the "real thing," a laboratory assignment deals directly with "real things" in all their complexity and imperfection, thus providing the need for team work, forming the multidisciplinary team, distribution and coordination of tasks and assignments, interaction and cooperation between team members, negotiation and exchange, that ultimately results in the development of students' networking and communication skills highly appreciated by future employers. Finally, conducting pre-defined and especially open-ended laboratory experiments presents an opportunity to observe how abstract theories and laws manifest (or do not manifest) themselves in operation of particular devices that reinforces theoretical background and provides the motivation for independent learning. While laboratory courses are crucial for the success of future engineers, it is also known that poorly equipped and trivial laboratory experiments "send a wrong message" to students and can do more harm than good [6]. Unfortunately, modern laboratory equipment and instrumentation consistent with the state-of-the-art engineering and industrial research facilities is very expensive. It is also very "touchy," requires intricate adjustment, and should be operated by well-trained personnel. In the hazardous environment of a student laboratory, this equipment has a very short life span and must be often serviced, repaired and replaced.

3 THE SYSTEM CONFIGURATION

Any laboratory experiment is intended to provide the students with an opportunity to visualize the laboratory hardware, to learn about its components, their functions and principles of operation, to establish the goal of the experiment, to design the experiment, to apply stimuli to the laboratory setup, to observe the hardware in action, to record data featuring the stimuli and the response of the hardware, and, finally, to process the recorded data. Therefore, the system presented herein addresses, facilitating remotely-operated laboratory experiments, implements all these functions utilizing the power of the Internet and computer technology to their full potential.

The visualization is achieved by compiling a library of digital photographs of the experimental hardware taken from different positions and angles of view and offering the user a specially designed image retrieval system to maximize the visualization effect. In addition, the use of web camera is expected. In order to learn about system components, the user is expected to browse the appropriate content area that provides a textbook-quality description of the relevant system component(s). Although we intend to provide the user with a number of suggested laboratory experiments, we would encourage our remote users to pursue their own goals and design their own experiments. Indeed, the role of a "lender of hardware" is even more consistent with the proposed technology than just the one of an educator. This perception drastically widens the functions of an Internet-accessible laboratory that could be appreciated by practicing engineers, researchers and hardware manufacturers worldwide. Indeed, the concept of "try first, then buy" has a potential for the market of the nearest future.

Any engineering experiment implies application of some strategically defined stimuli and recording the system responses. Our system has the facilities for the generation of typical communication signals, and offers the choice of the regime operation of the hardware. In addition, a user can apply his or her own input signals recorded in a data file. It is important though that specially designed software routines would automatically limit magnitudes and frequencies of the input signals protecting the laboratory hardware from possible damage. The ability to observe the response of the laboratory setup to the applied stimuli provides a very important learning experience. The response of laboratory hardware, converted by a number of sensors and computer interfaces in signals and recorded in a data file becomes immediately available to the user who has the ability to utilize data processing and plotting facilities and/or download this data file for further processing.

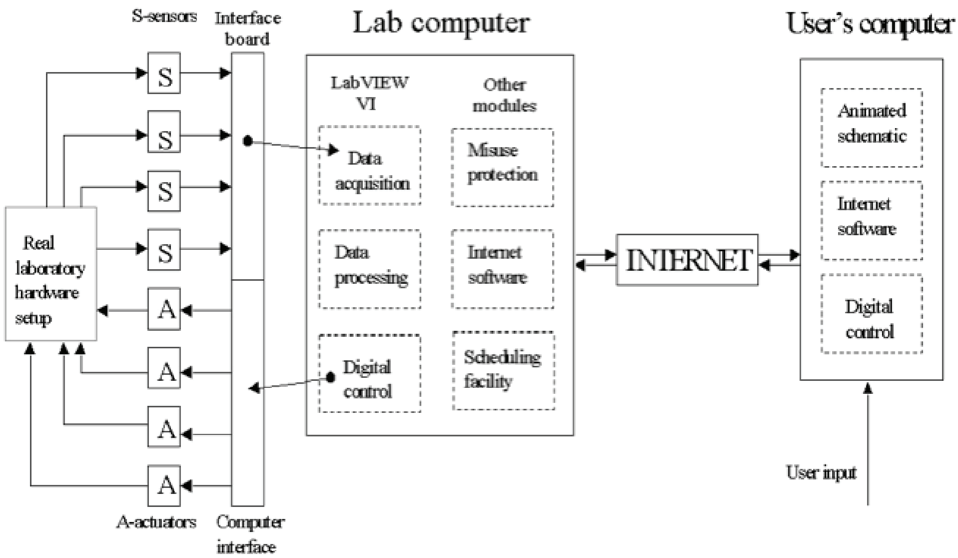

FIGURE 1. *System configuration.*

A schematic in Fig. 1 represents the overall configuration of a laboratory setup accessible via the Internet. It could be seen that a real hardware setup is interfaced with a lab computer that, operating through a system of actuators (A) and sensors (S), performs control and monitoring tasks.

4 THE WORKING PROTOTYPE

Mounted on the roof tops of two buildings on the Binghamton University campus are two identical laser communication modules manufactured by fSONA (SonaBeam 1250-S). Each module has two laser diode transmitters and a 10 cm receiver. The aperture layout of each terminal is shown in Fig. 2. Peak laser output power for each laser diode is approximately 140 mW, which provides up to 280 mW of total power. Data transmission rates for the device can be varied between 100 and 1448 Mbps. The environmentally sealed units provide a free space link utilizing a 1550 nm wavelength in the infra-red region, hence allowing eye-safe operation. The fSONA system operates within the described infrastructure facilitating remote access to the link head's locations and providing network connectivity for communication data. Laser power for each transmitter can be adjusted independently, as needed.

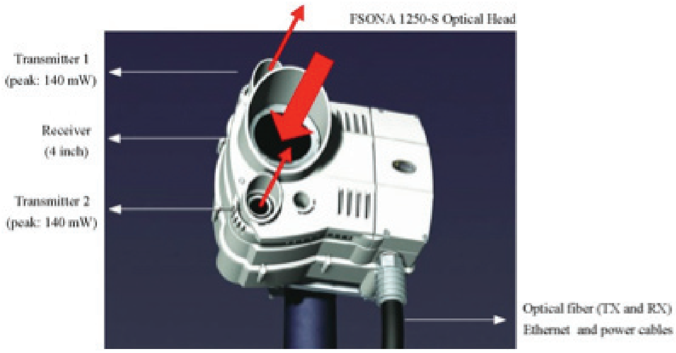

FIGURE 2. *Laser communication terminal.*

A dedicated computer is equipped with two Ethernet cards that are used to send and receive communication bit streams. Two media converters, which convert data from the Ethernet card form (electrical) to optical and vice-versa, are used to connect to the link head's fiber optic communication channels, as shown in Fig. 3.

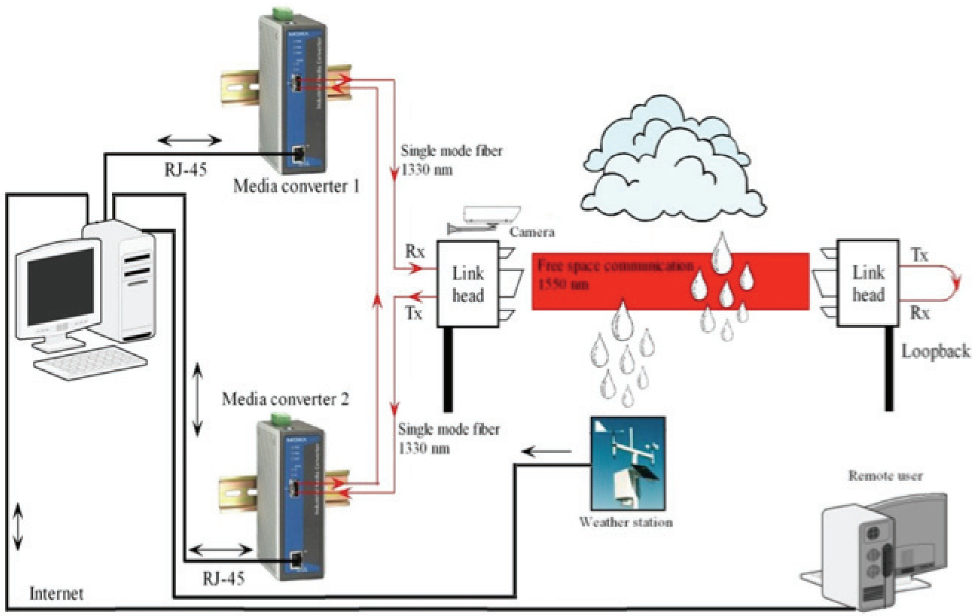

FIGURE 3. *Experimental system.*

The data transmission to the link head from the media converter is performed using 1330 nm wavelength via a single mode fiber. The data is sent in free space from one link head to the other using 1550 nm wavelength and then it is looped back. Once received, the second media converter is used to convert the optical signal at 1330 nm back to electrical to be sent to the second Ethernet card on the same interface computer.

In addition, our system is equipped with a weather station, a collection of sensors to measure temperature, humidity, wind speed and direction in weather-related experiments and a video surveillance system intended to provide visualization of the link path and qualitative characteristics of the channel.

All hardware in our system is controlled via a LabVIEW instrument panel, which integrates the communication channel, weather station and camera. A screen shot of the LabVIEW front panel is shown in Fig. 4. This graphical user interface is accessible via a standard web browser and includes laser link-head control, weather information, live view of the laser beam path, link speed control and file sender.

FIGURE 4. *Graphical user interface (GUI) of the experimental system.*

Two modules on the upper-left of the GUI window provide control and real-time status information for both link heads. The module in the upper-right corner presents all available weather information. A live feed window is located just below it.

Lastly, control of the laser link's communication can be achieved by switching the bit rates between 100 mbps and 1 Gbps. In addition, the user can transmit data over the link using a SEND command and the corresponding module sends a preset pattern of bits to be later used for bit error rate measurements.

5 RECOMMENDED EXPERIMENTS

Characterization of a high-performance communication link is a task typical for a practicing electrical or communications engineer. While it is expected that the facility users will develop their own experiments, the following examples can be suggested.

Link analysis under various conditions. Measurements of the received power is a common and practical task in link budget analysis. Since all parameters of the laser communication system are known, this experiment requires students to perform calculations for a given transmitted power and verify if the results are reasonably close to the measured signal. This could be repeated for different values of the transmitted power and for situations when one of the two transmitter diodes is disabled, since all these options are available through our interface software. It is very likely that the results will be noticeably different (and quite educational), since the standard link budget analysis requires the knowledge of absorption, scattering and turbulence parameters of the communication channel, still unknown to the students. Therefore, the average collected power and average intensities could be compared to previously calculated values to evaluate the effect of scattering and absorption and to find an approximate value of the extinction coefficient. Weather sensors will be used along with a web camera to get current information on the channel conditions. The parameters of interest include outside temperature and humidity, wind speed and direction, precipitation, fog, sunny/cloudy sky, etc. Measurements collected at different times or on different days will provide very useful data for correlation analyses. For example, students will be able to find which weather factors are most responsible for the optical turbulence effects or the signal fades. We intend to keep a sufficient data history on the server, so that it would be available to those users who did not spend enough time collecting their own experimental data.

Effect of transmitted power on error rates. This and all subsequent experiments explore the impact of various factors on the error rates of the system. Typically, this information could be obtained through textbook learning and computer simulation studies. However, most textbooks provide detailed description just of the additive white Gaussian noise, often disregarding many factors contributing to the bit error rate in real-world communication systems. Experimental studies would provide students with better insight into the complex interplay of the underlying physical phenomena. For example, experiments will emulate the loss of received signal power that causes random errors arising in a way that is equivalent to an increased noise level. Thus, by controlling the transmitted power it is possible to explore the standard textbook bit error performance. During the experiment the transmitted power can be controlled by the available terminal software and the resulting bit error rate will be measured. This provides students with a hands-on exposure to the realities of communication systems and will allow them to experience verification of the ubiquitous bit-error-rate curves presented in textbooks.

Effect of Transmission Medium on Error Rate. The experimental environment offers the luxury of having the actual and received information at the same time, and therefore is conducive to various error analysis studies, including the effectiveness assessment of various error mitigation technologies. Many conditions result in a random source of bit errors that are uniformly spread in time; such errors can be mitigated by binary error correction codes. However, other real-world sources can result in bursts of errors that can seriously reduce the effectiveness of correction codes effective for addressing random bit errors. One particular error correction code that is very effective against burst errors is the Reed-Solomon code, whose effectiveness is due to the fact that it is inherently a non-binary code. That is, the elements that make up a codeword are not bits but rather are symbols in a q-ary alphabet and are therefore able to correct a specified number of q-ary symbol errors within each codeword. Thus, a large burst of bit errors will lead to a smaller number of symbol errors that can then be effectively corrected by the code and tested on our system.

6 CONCLUSION

The-Internet-accessible engineering laboratory is a novel concept in distance learning. While laboratory classes are a necessary component of any engineering curriculum, it can dramatically enhance the quality of education on the global scale. An experimental setup featuring laser communication system operating within a special infrastructure facilitating full remote access to the hardware is described. The system offers a set of pre-defined and open-ended experiments.

7 ACKNOWLEDGEMENTS

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271 MECATAS – TEACHING AND LEARNING MODEL FOR CONTROL AND AUTOMATION ENGINEERING BASED ON THE MEANINGFUL LEARNING THEORY

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ABSTRACT

This paper presents a pedagogical model for teaching and learning control and automation engineering with a focus on meaningful learning (MECATAS). This model consists of three main elements: 1 - cognitive theories of learning, to provide the basis for model construction and analysis of results; 2 - proposed technology platform, to assist students in developing activities related to professional practice; 3 – instruments for the development of learning and assessment mechanism.

Keywords: Pedagogical model, Meaningful learning, Control engineering.

1 INTRODUCTION

Cognitive learning theories set the foundation for the creation of pedagogic models that are used around the world. These models are responsible for educational structuring in all possible processes, considering the realities of each country.

A pedagogical model is a composition of some elements, each of which play an important role in the set of elements and are therefore essential for the structure of the model.

There is no consensus on the true definition of a pedagogical model. Many authors consider a pedagogical model to be a mere theoretical outline that is used as a basis for pedagogical practice. This is the conception of a pedagogical model adopted by [3],[8] e [4].

In this article, the concept of the pedagogical model will be extended to cover other elements that are not necessarily theoretical, approaching concepts of pedagogical methodology or pedagogical method. The term "model" is maintained due to the scope of the proposal.

The basic elements of any pedagogical model are: 1 – a learning theory; 2 – an object of study that comprises content, practice and technological platform (in the broad sense of the word); 3 – an assessment mechanism.

According to [4] the recommendations of ABET – Accreditation Board for Engineering and Technology, a North-American organization that determines specific quality criteria for each qualification, graduate courses should stimulate the capacity to apply knowledge of mathematics, science and engineering; project and conduct experiments; analyze and interpret results; design a system, component or process to meet certain requirements; participate in multi-disciplinary teams; identify, formulate and solve engineering problems; understand the nature of professional ethics and responsibility; communicate effectively (written and oral); understand the impact of engineering solutions in the social and environmental context; seek permanent learning; and use modern techniques and tools for engineering practices.

In light of these requirements, research should be conducted on the development pedagogic models that better comply with current qualification needs and professional demands of the work market in relation to engineering.

According to the economist Marcos Formiga, advisor to the board of the Confederação Nacional da Indústria – CNI (National Industry Confederation), the dropout rate for engineering courses is over 50%. Data from the Instituto de Pesquisa Econômica Aplicada – IPEA (Institute for Applied Economic Research) shows that one of the possible causes of this problem is distance between course curricula and solution of concrete problems imposed by market reality.

Consequently, there is a need for determining the target audience of the pedagogical model. Research, namely controlled pedagogic educational studies, is essentially empirical.

A pedagogical model is always proposed for a target audience. In this study, the target audience is students of the Control and Automation Engineering course. The research test profile is 8th course period students of the Instituto Federal Fluminense (IFF) registered in the curricular component called Advanced Control.

The next step after defining the target audience is to define a cognitive learning theory that is better adapted to this audience; a theory that is based on studies and a focus on the segment that will be studied or stimulated. In a pedagogical model for teaching engineering, for example, it is not advisable to use cognitive learning theories that consider the learner from the standpoint of cognitive development stages [7].

The object of research or stimulation should be related to cognition .
Although emotional aspects, interaction with the environment and learning styles influence the knowledge construction process, the learning process strongly determines the internal effects on the cognitive structures of the individual, especially in the dynamic evolution of knowledge organized in these structures. To be more exact, we are dealing with: organization, understanding and extension of knowledge.

During the teaching-learning process there are moments in which the professor (expositive classes) and the student (production or authorship) alternate the role of main actors of this process. As this process is dynamic and developmental from a learning standpoint, it is important to determine moments in which the individual is assessed.

The next sections of this study are outlined within this context. Section 2 presents the theoretical basis of the proposed model. Section 3 outlines the proposed pedagogical model, and section

4 and 5 discusses the educational-pedagogical experiment conducted for the validation of the proposed pedagogical model and obtained results. Finally, section 6 presents the final considerations of this study.

2 THE MEANINGFUL LEARNING THEORY (MLT)

Meaningful learning is adopted as the central learning theory in this study due to its relation to the study of engineering. Typically, classes in an engineering course comprise a target audience that has already passed the cognitive development stages defined by [7], that is, students that have the necessary cognitive structure to conduct operations on abstract concepts, which means they are in the formal operational stage. Students attend expository classes and discovery classes and, in both cases, have some form of meaning schema that favours learning. [2] considers that this meaning schema is actually the subsumption needed for the emergence of meaningful learning.

The meaningful learning theory was created by [2] and later promoted and investigated by researchers of various knowledge fields such as [5], [9] and others.

Ausubel proposed that learning must be meaningful in order to have a modifying effect on the cognitive structures of the individual. Based on this premise, Ausubel suggests the need to define meaningful learning and its opposite, which is non-meaningful learning. According to [2]:

> *It is important to acknowledge that meaningful learning (regardless of type) does not mean that new information simply forms a link with pre-existing elements in the cognitive structure. On the contrary, only mechanical learning results in a simple, arbitrary and non-substantive connection with the pre-existing meaningful structure. In meaningful learning, the information acquisition process results in change, both of newly acquired information and the specifically relevant aspect of the related cognitive structure.*

Ausubel also emphasized that in order for learning to be significant, it requires some specific aspects: learner motivation; interest in learning the presented content; potentially meaningful study material and a learner with the subsumption needed to learn the content.

Subsumption is a term coined by Ausubel to represent the prior knowledge of the learner on any given content that is present in his or her cognitive structures.

In spite of understanding this concept, it is impossible to differentiate meaningful learning from non-meaningful learning because learners manage to memorize symbols, concepts, propositions and even solutions to problems.

Some strategies, however, manage to overcome this inconvenience of learner simulation of meaningful learning, such as formulating questions of main involved concepts in a different manner to the manner in which they were presented.

In order to reasonably understand how the assimilation process occurs during meaningful learning, we can resort to the schema presented by [9]:

It is based on the assumption that new information with potential for meaning is presented and then related to a subsumption that already exists in the cognitive structure. The result is a product of this interaction that leads to a new complement of modified information and modified cognitive structure, that is, the new information changes and the subsumption changes and becomes more comprehensive and solid to be used for a larger set of new information.

This can be summarized and expressed as follows:

The concept a → a' when in contact with its corresponding subsumption A A, which also becomes A', so a . A → a'. A'.

The next section presents the proposed theoretical model of this study and existing relation between its constituent elements.

3 THE PEDAGOGICAL MODEL

The pedagogical model proposed in this study was created from learning theories with a cognitivist focus. Its conception was based on application in pedagogical practice inherent to the control and automation engineering course and, as such, the students of this type of bachelor degree course are the target audience of the model.

MECATAS is an acronym that is based on the following proposal: a pedagogical model for use in the teaching-learning process in control and automation engineering courses essentially based on the meaningful learning theory.

This model comprises three main elements: 1 – cognitive learning theories to provide a basis for model construction and results analysis; 2 – proposed technological platform to help students develop activities related to professional practice; 3 – instruments for learning development and assessment.

Among the elements present in MLT, the following elements were highly considered in the model and study:

- Subsumptions, accessing prior knowledge in the cognitive structures of the learner and singularly reaching support points for the establishment of new substantive and non-arbitrary connections with new assimilated concepts.
- Prior organizers, created from identification of the subsumptions and operating as potentially meaningful material for use in pedagogical practice.
- Assimilation process of new concepts in order to understand the dynamic evaluation of the existing concept network in the cognitive structures of the individual.
- Basic knowledge organization elements – based on MLT – as progressive differentiation and integrating reconciliation.

The proposed technological platform [1] is extremely important in this model given its potential for experimentation and validation of the end-activity of the control and automation engineer, that is, it supports the process of design, projection and testing of automatic control systems. This is possible because it associates the computer potential of MATLAB® to robustness in terms of validation and practical experimentation of industrial prototype processes such as the mini-distillery.

In addition to these MLT aspects, other theories were considered in the creation of the model, namely in relation to the assessment process. Items include concept maps that provide a solid theoretical basis of MLT and potential for a wide range of uses within the proposal, albeit the mere representative nature of these maps.

The theory of mediated learning experience that defines the evaluation requirement during the teaching-learning process and not only in stagnated moments was used in model design for the assessment process. Several assessment moments were determined in the form of tasks that were later analysed under MLT to detect manifestation and evolution.

Figure 1 shows the conceptual model and constituent elements for the proposed pedagogic model.

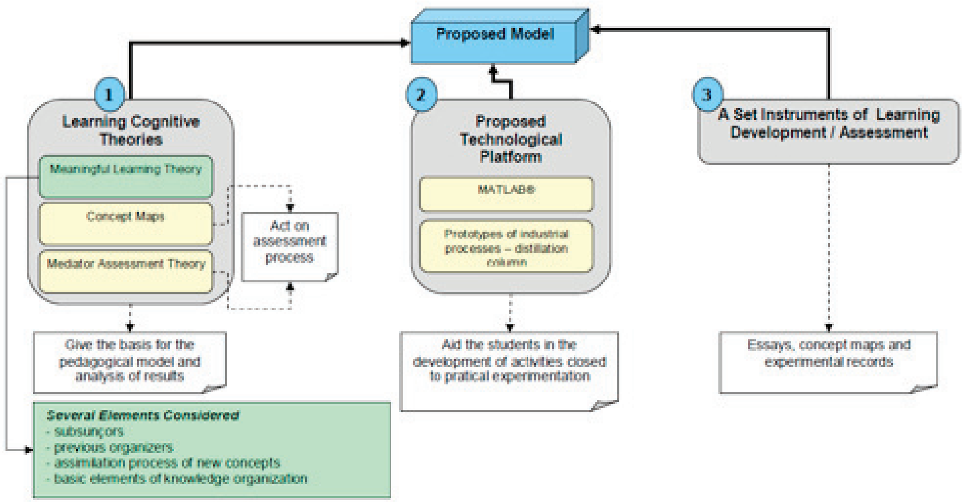

FIGURE 1. *Conceptual model of the proposed pedagogical scheme.*

Section 4 comprises a characterization of the pedagogical experimentation and presents constituent elements inspired by the model based on the proposed technological platform.

4 THE PEDAGOGICAL EXPERIMENT

Research in education has a tendency for qualitative analysis of events and data that are observed and recorded according to subjectivity relative to the teaching and learning process.

In the research conducted for this study, number identification of the studied elements was not objective. This fact implies the need for scientific investigation in the form of a case study where an assumption does not require statistical results but attempts to answer a research question:

> *"Does the proposed pedagogical model allow meaningful learning?"*

This question may not be fully answered, but an attempt to answer the question led to research in the form of a case study based on pedagogical experimentation that was conducted every six months and repeated in three different class forms of the Control and Automation Engineering course at the IFF, during the terms 2010-1, 2010-2 and 2011-1, respectively with 38, 18 and 21 students.

In order to detect the elements of interest in this study and provide tangible records based on MLT, the following research instruments were used: subsumption questionnaire, proposal relevance questionnaire, concept maps, research and text, teacher and student reports and problem solving. Only results of the concept maps are presented in this study.

Considering that the model has production/authorship moments for the learner to develop and learn, the experiment also has instruments to record production during these moments for later analysis. This strategy of inserting the research instrument during application of the pedagogical model aims to dissociate the assessment process from pedagogical practice, which is one of the requisites of the Theory of Mediated Learning Experience [6].

5 RESULTS

Only concept maps were used to express results due to their predominant significance in this study.

Production/authorship moments were defined by the professor during the entire term and requested as tasks to be delivered on specific deadlines. Grades for these tasks were included in the final average of the Advanced Control grade that was recorded in the IFF academic system.

Requested concept maps were based on the following content:

- Advanced control – initial map for identification of the prior organization of concepts in the cognitive structure of the students;
- Artificial neural network – map to verify cognitive organization in intermediate curricular content;
- Fuzzy control and logic – map to verify advanced concepts of content;
- Advanced control – final map to verify understanding of concepts during the term and cognitive organization.

A map categorization model was created in grading regions based on the presence or absence of elements that denote meaningful learning. In spite of the discretization tendency of map analysis, this method is only used to allow clearer organization of results as reading of all maps and comments would be tiresome. Table 1 shows the reference model for concept map analysis.

TABLE 1. Definition of concept map level according to present MLT elements.

Map levels	MLT elements in the map
1	Morphologic hierarchization, ramification, arbitrary connections.
2	Progressive differentiation.
3	Integrating reconciliation, progressive differentiation.
4	Transversal elements, generalization understanding.

The graphs of figures 4-8 present data of study group 2010-1 and show a statement of frequency of map types. It is important to highlight that the adopted methodology for application of the pedagogical model based on the concept maps was preserved and maintained for the three study groups.

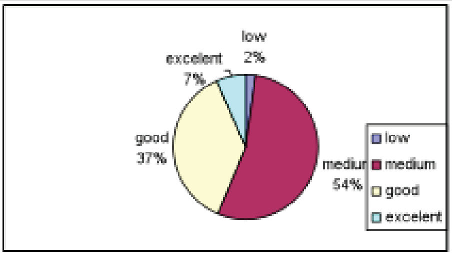

Figure 4. General map percentage.

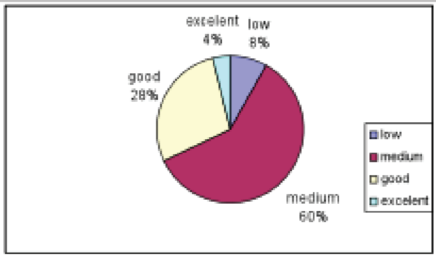

Figure 5. Map percentage (1st).

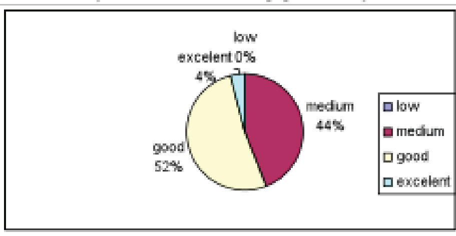

Figure 6. Map percentage (2nd).

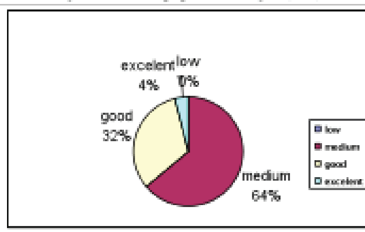

Figure 7. Map percentage (3rd).

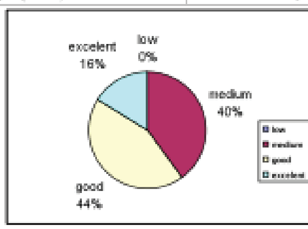

Figure 8. Map percentage (4th)

Analysis of Figures 5-8 shows that the number of type-2 maps is only exceeded by the number of level-3 maps in the 2nd and 4th maps. If we analyse the moments in which these maps were requested, they would coincide with the moments of the final period in which subjects are finalized, preceding performance evaluations.

6 CONCLUSIONS

Results show the predominance of the level 2 map. Level 2 maps are characterized by the striking presence of the progressive differential element. Frequency of level 4 maps is relatively low, showing the difficulty of most students in making transversal connections and understanding and generalization of existing concepts. Moreover, level 2 and 3 maps contemplate important MLT elements.

Although the experiment was limited to study groups of Advanced Control, it can be extended to groups of other disciplines as the pedagogical model provides a basis for application in several curricular course components. The pedagogical model was fully presented and results for validation were recorded and analysed within the scope of MLT.

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272 OPEN AND DISTANCE LEARNING FOR ENGINEERING; OPPORTUNITIES AND CHALLENGES

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ABSTRACT

The majority of the ~4000 students currently studying for engineering qualifications with the Open University (OU) are mature students in full-time engineering related employment who study part-time through distance learning. This, together with the OU's open access policy (there are no formal academic entry requirements to the programme) and the range of different study pathways available, results in a particularly diverse student body and presents us with a range of challenges. In this paper we describe our existing approach in three particular areas, and discuss planned initiatives to improve our provision. The three areas considered are: the need to ensure that new students are adequately prepared for study at the required level; the challenge of facilitating and assessing group work effectively within a distance learning environment; the limitations of relying on generic mathematics modules not specifically tailored to engineering. We will also touch on how imminent changes to UK higher education funding are likely to impact on engineering education within the OU.

Keywords: open access, distance learning, engineering, design, mathematics.

1 INTRODUCTION

The Open University (OU), based in Milton Keynes with thirteen national and regional centres across England, Scotland, Wales and Northern Ireland, is the largest university in the UK with over a quarter of a million registered students [1]. The average age of an OU student is thirty two and most study part-time. This total includes approximately four thousand students currently studying towards an undergraduate Bachelor of Engineering (BEng (Hons)) or Engineering Foundation Degree (Eng FD): we will focus here on the BEng (Hons). The majority of our engineering students are in full-time engineering related employment.

The OU has an open access policy and, with very few exceptions, there are no formal academic entry requirements. Some students on the engineering programme will join us with no previous educational qualifications (PEQs), though often with extensive practical vocational experience, whilst others may bring transferred credit from related qualifications, or may already have degrees in other subjects. The university as a whole has a relatively high proportion (~5%) of students with disabilities or additional requirements; this proportion is lower in engineering related subjects and tends to be more focused on specific learning difficulties such as dyslexia.

OU modules are delivered by supported distance learning. Most engineering modules are still centred on printed texts, but these are increasingly being supplemented or replaced by a growing range of online resources. Learning and assessment resources are produced centrally, whilst day to day academic support is provided by a UK-wide network of part time tutors, typically through a mixture of non-compulsory face to face tutorials, online synchronous tutorials and ongoing support via telephone, email and module forums. Students can and do study in a wide range of situations and locations, although internet access is becoming essential for successful study.

1.1 Changes for 2012

The general context outlined above results in a particularly diverse student body, and this poses many challenges for the engineering programme. The following sections of this paper will focus on three particular areas: the need to ensure that new students are adequately prepared for study at university level; the challenge of facilitating and assessing group work effectively within a distance learning environment; the limitations of relying on generic mathematics modules not specifically tailored to engineering. In addition, recent changes to higher education (HE) funding mechanisms in England [2] are likely to have a profound effect on our student population. Whilst the possible effect on student numbers or student profiles for OU engineering qualifications is hard to predict, administrative changes made necessary by the new funding regime afford us exciting new opportunities to offer more tailored support to our students.

At the time of writing (April 2012) students register for modules one at a time, accumulating HE credit for each module that they successfully complete. Individual modules can generally count towards any one of several different qualifications. When a student has achieved sufficient credit at the required levels of study they can 'cash in' their modules for a qualification: for a named degree such as the BEng (Hons) there are specific requirements that must be fulfilled. Thus, although we can identify the students studying a particular module, we cannot be certain which students are aiming to complete a BEng (Hons) until they have completed their studies and cashed in their credit. Furthermore, students can complete modules in any order and, despite our best efforts to offer advice and guidance, there is no guarantee that they will follow a particular recommended route through their degree.

From October 2012 this situation will change. New undergraduate students will be required to register for a qualification right from the start. The flexible BEng (Hons) that we currently offer will be replaced by a new qualification within which there are a small number of tightly specified pathways. For the first time in many years we will have the luxury of knowing not only who our students are, but which modules they will be studying and in which order! We are also well aware that they will be paying (or owing) considerably more for their studies and the consequences of failure will be far more significant, financially, than they are now.

2 CURRENT CHALLENGES, NEW OPPORTUNITIES

In sections 2.1, 2.2 and 2.3 respectively we look in more detail at issues around preparedness for study, online group work and mathematics for engineering.

2.1 Ready for Study?

For new students with few or no formal academic qualifications, or students who are returning to study after a long break, the OU has until recently offered 'Openings' modules in several subject areas. These provide some subject specific content but are primarily designed to develop study skills. There has not been an Openings module specific to engineering, so students have been more likely to embark directly onto our 30 credit introductory level one module in engineering T173: Engineering the future. The module had its first presentation in 2000 and is in the process of being updated. Retention and pass rates on this module have been relatively low compared to other level 1 modules in the faculty, and it performs poorly when considered alongside recently produced modules in other subject areas such as environment or mathematics. However, the financial investment associated with a single module has been relatively small (with many students gaining financial assistance from the University) and it has been straightforward to switch from one subject area to another, so it might be argued that the risk for the student in embarking directly onto a level 1 engineering module, regardless of PEQs, is low.

TABLE 1. New students gaining credit for T173 for presentations starting between October 2009 and February 2011, according to previous educational qualification.

Previous educational qualification (PEQ)	Number of students	% of students starting T173 who gain credit for T173
No PEQs	32	28
< 'A' level	492	42
'A' level or equivalent	604	52
HE qualification	433	58

Table 1 shows how the percentage of new students gaining credit on T173 varies according to PEQ for four presentations of the module starting between October 2009 and February 2011. It is important to note that the figures include students who have switched to a different module or decided to reduce their study intensity, so some of these students will have gained credit on other modules. Clearly, students' previous educational qualifications have an impact on their likelihood of success and as the OU is committed to open access and widening participation it is essential that we improve students' chances of success and their progression through the BEng (Hons).

From October 2012, with considerably increased costs and qualification (as opposed to module) based registration, the need to ensure that students are suitably prepared to start their degree becomes far more significant. The new funding regime for England means that students will be eligible for a loan to study a level 0 access module, as long as this is used as a route into a qualification. That is, they will be able to access a loan for 390 credits of study. The Open University will be reconfiguring its access curriculum from autumn 2013 and will include a 30 credit, level 0, module specifically for Science, Technology, Engineering and Mathematics (STEM) students. This module will aim to address the needs of students with a wide range of previous educational experiences and develop their confidence in their ability to study at HE level. It will also need to provide a smooth transition to level 1 and orient the students towards the Open University and its methods of supported open learning. Part of the challenge of producing this module will be to provide sufficient subject 'tasters' to enable students to make an informed choice about their subsequent qualification pathway.

2.2 Group work at a distance

A requirement for team-working is included in almost all national standards for the education of engineers, including the UK Standard for Professional Engineering Competence UK-SPEC [3]. This is a particular challenge when students are studying part-time through distance learning. At present the OU BEng relies heavily on residential weeks held at host universities both for developing practical skills and for providing opportunities for group work. As online tools for collaborative working become more widely available and our understanding of how to use them effectively develops, new possibilities are emerging. One interesting development within the OU has been the production of a highly successful Team Engineering module, which forms a compulsory part of the integrated Master's degree in Engineering (MEng) and other postgraduate qualifications. Team engineering uses a combination of two residential weekends at the beginning and end of the module, with online collaboration via wikis and video-conferencing in between, to support groups of four to seven students as they work together on an engineering project over a 32 week period [4]. The creation of teams at the initial residential weekend has proved effective in building good working relationships and the module has not suffered the levels of student resistance to group working reported elsewhere [5]. The potential to record the online elements provides a clearly visible record of each student's participation that can be used in combination with appropriate assessment tasks to judge individual contributions.

Another initiative that facilitates collaborative working for students and has the potential to develop peer assessment is Open Design Studio (ODS). This was developed by the OU as part of U101, Design thinking – a 60 credit, introductory level 1 module. ODS enables students to share images of their design work and allows others to comment on their work [6]. Figure 1 shows an example of a student's work on their home page.

Building on experience from U101 and other modules we are planning to introduce an element of online group working into the new version of our introductory engineering module, centred on the Open Design Studio. Figure 2 shows a rough outline of how the online activity will be developed through the module, gradually introducing tools and building skills within structured activities linked to the subject content of each block. Each element of the activity will feed into the assessment for that block, providing an added incentive for students to take part. By providing a gentle early introduction to the use of collaborative online tools at the start of the BEng we hope to foster a greater feeling of community amongst our students and reduce the isolation of distance learning, as well as contributing to the achievement of learning outcomes related to team work.

FIGURE 1. *A student homepage in Open Design Studio.*

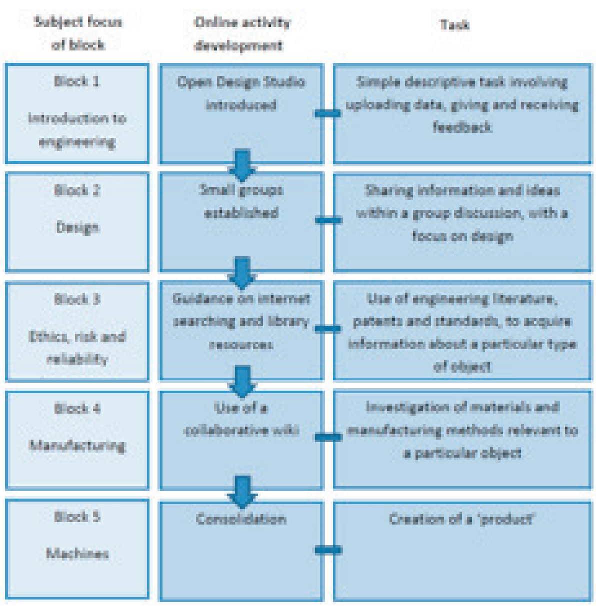

FIGURE 2. *Outline of planned online activity*

2.3 Maths for engineers

The increasingly wide range of mathematical preparedness amongst entrants to engineering degrees, and the difficulties of dealing with their different needs, has been recognised as a problem for many years [7]. Several different approaches to addressing this have been trialled, with varying degrees of success [8]. The problem of poor mathematical skills on entry is particularly acute in the OU, where students come from a wide range of educational backgrounds and may not have studied mathematics formally for some time. Many of the traditional approaches, such as additional lectures or drop-in problem classes can be hard to replicate in a distance learning environment. We provide a variety of online diagnostic and support material, which typically includes practise questions with multiple variants that can be marked instantly: an example can be seen at http://mathshelp.open.ac.uk/. The range of question types available and the sophistication of the feedback that can be provided is a key focus of institutional research within the OU and continues to develop. See for example [9, 10].

In addition to the maths embedded in the core engineering modules, OU engineering students are currently required to study at least one specified 30-credit maths module. From October 2012 the requirement will increase to 60 credits of specified maths modules. These are generic mathematics modules designed primarily to suit the requirements of the mathematics programme, but which are also utilised by other subject areas, particularly (but not exclusively) engineering and science.

Under the module-based registration system it has not been possible to distinguish between students studying maths modules with different qualification aims. All students are presented with the same material, delivered in the same way by a tutor assigned in most cases according to geographical location. They take the same assessments and are judged by the same standards. However, students have had some choice over the level at which they start their mathematics studies; those struggling with the 'standard' maths offering have been able to switch to a 'gentle start' option, progressing to the more demanding standard module at a later stage.

Under the new qualifications framework it will become possible to easily distinguish between cohorts of students on particular study pathways, presenting new opportunities to tailor maths support more closely to the needs of particular groups of students. However, the possibility of switching to a 'gentle start' has effectively been removed for BEng (Hons) students since the new tightly defined qualification pathways do not include this option. There is no resource available for developing bespoke maths modules for our engineering students, but various interventions are under consideration to improve the advice and support that we can offer our students. It is important to remember that most of our students are combining study with work, family and other commitments and often have little or no potential for increasing the amount of time available for study: merely giving them extra work to do is unlikely to succeed. Table 2 lists current provision together with possible interventions that are under consideration at different points in the study calendar. We intend to trial some or all of these over the next few years in order to judge the most effective way to improve the support we offer to our students.

TABLE 2. Maths support options for OU engineering students.

Point of intervention	Current provision	Possible intervention
Pre-registration	Online diagnostic quizzes are available for students to test whether they have the required maths skills, but are not compulsory.	Students may be required to complete a maths diagnostic quiz before registering for an engineering qualification and directed towards preparatory material where necessary. This could be linked to registration.
Allocation to tutor groups	Tutor groups contain a mixture of students with different qualification aims.	Engineering students could be grouped together and assigned to tutors with specific background/interests in engineering.
Student struggling early in module	Students may be advised to begin with a module at a lower level and try again later.	Students could be advised to temporarily reduce their study intensity, and provided with support to complete preparatory material.
During the maths module	Routine support from tutor, feedback from written assessments and online quizzes, optional tutorials, limited provision of one to one support sessions to address specific needs.	Greater emphasis on engineering relevance of module material and prioritization of certain aspects over others. Online support sessions to cover particular areas of difficulty.
At the end of the module	No distinction between students with different qualification aims.	Thresholds for progression, or weighting of assessment components, could differ according to qualification aim.

3 CONCLUSION

In this paper we have summarized a few of the challenges currently facing the Open University in delivering undergraduate engineering qualifications through open and distance learning, and some of the steps that are being taken to address them. These issues have been brought into new focus by recent changes in the funding of HE in England, which have necessitated major changes in the way the OU organizes its provision. The changes offer some potential benefits, but by reducing the flexibility available to students they increase the responsibility of the engineering programme to ensure that they make the right initial choices and are well supported throughout their studies. Open access is a fundamental principle of the Open University and we are committed to retaining it along with a commitment to widening participation. The production of a new access module specifically designed for students intending to study STEM subjects can only benefit students who have low previous educational qualifications or who have been out of the education system for a long time.

The OU specializes in distance learning and has built up an excellent reputation for the quality of our provision, but effectively facilitating and assessing group work in engineering is a particular challenge. A rewrite of our introductory level 1 module provides an opportunity to imbed recently developed web resources that enable encourage students to collaborate together in a supervised and structured online environment. Finally, the new ability to distinguish between students studying generic mathematics modules towards different qualification aims provides us with an opportunity to provide more tailored mathematics support to students within the engineering programme. We would welcome opportunities to collaborate with other interested parties on all these issues.

4 ACKNOWLEDGEMENTS

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