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Session Mo1: Experiential Learning
Time: Monday, August 25th, 1:30 pm-3:10 pm
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Mo1_1	"A multidisciplinary module-based biotechnology lab course: forging bridges between Biochemistry and Chemical Engineering experiential-based learning" Felicia Vulcu, Meagan Heirwegh, Kim Jones and Rena Cornelius, McMaster University, Canada.
Mo1_2	"Development of Traditional Skill and Technology Learning Method Using Digital Tools" Taisuke Shirakawa, Yoshifumi Ohbuchi and Hidetoshi Sakamoto, Kumamoto University, Japan.
Mo1_3	"Teaching Integrated System Design: Case of Mechatronics Project based on a Line-Following Robot" Reiner Schmidt, Tom Wanyama and Ishwar Singh, McMaster University, Canada.
Mo1_4	"Teaching Electromagnetics through a Combination of Blended Learning and Experiential Learning" Mohamed Bakr, McMaster University, Canada.
Mo1_5	"Aircraft Motion Simulation in Time Domain- A Useful Tool in Flight Mechanics" Abdulhamid A. Ghmmam and Ahmed A. Makhlufi, University of Tripoli, Libya.

Session Mo2: Novel Teaching Approaches in Engineering
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Mo2_3	"The Requirements for an Electric Circuits Course in the "Modern" World" George Gibbon, University of the Witwatersrand, South Africa.
Mo2_4	"Teaching Technical Communications through Formative Assessment" Kim Jones and Emily Cranston, McMaster University, Canada.
Mo2_5	"Laboratory Scaled Plug-in Electric Vehicles Car Park Infrastructure Design and Implementation" Osama Mohammed and Tan Ma, Florida International University, United States of America.

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Mo3_2	"Integrating RFID Technology into a Course in Mechatronics" Heshan Fernando, Colin Lounsbury and Brian Surgenor, Queen's University, Canada.
Mo3_3	"Creating Future Engineering Researchers Beginning at Undergraduate Level" Anant Kukreti and Temesgen Aure, University of Cincinnati, United States of America.
Mo3_4	"Scholars of Excellence in Engineering and Computer Science Program, an NSF S-STEM Grant: Assessment and Lessons Learned – First Award" Karinna Vernaza, Scott Steinbrink, Barry Brinkman and Theresa Vitolo, Gannon University, United States of America.
Mo3_5	"Development and Evaluation of a Material Balance Concept Inventory" Indumathy Jayamani and Susan Masten, Michigan State University, United States of America.

Session Mo4: Learning Evaluation
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Mo4_2	Development, Teaching, and Evaluation of an Undergraduate Foundational Course in NanoElectronics" Syed Omar, Amit Verma and Reza Nekovei, Texas A&M University-Kingsville, United States of America.
Mo4_3	"How to Measure the Quality of Teaching by Graduate Assistants in Undergraduate Engineering Courses" Daniela Pusca, Jacqueline Stagner and Hoda Eiliat, University of Windsor, Canada.
Mo4_4	"From 'quality assurance' to 'quality enhancement'" Vidar Gynnild, Norwegian University of Science and Technology, Norway.
Mo4_5	"Assessment of Engineering Course Outcomes: Case Study" Bilal El-Ariss and Amr Sweedan, United Arab Emirates University, United Arab Emirates.

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Mo5_2	"Development of Ethics Assessment Strategy for Senior Undergraduate Engineering Physics Course" Minha Ha and Shinya Nagasaki, McMaster University, Canada.
Mo5_3	"Implementation and Integration of Phasor Measurement Units in Laboratory Based Smartgrid Testbed" Osama Mohammed, Ali Mazloomzadah and Mehmet Hazar Ciltuglu, Florida International University, United States of America.
Mo5_4	"Development of Evaluation Equipment of Electric Vehicle for Student Project Team" Masakazu Nishi, Yoshifumi Ohbuchi, Hidetoshi Sakamoto and Hisahiro Inoue, Kumamoto University, Japan.
Mo5_5	"Urban Mega Transit Projects in Capstone Engineering Design Course: Win-Win Educational and Professional Development Strategy" Benjamin Colucci Ríos, University of Puerto Rico at Mayagüez, Puerto Rico.

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Mo6_2	“Collaborative Testing as a way to Enhance Student Learning” Kevin Dunn and Terry McCurdy, McMaster University, Canada.
Mo6_3	“An approach to teach software architecture quality driven by non-functional requirements” Renato Andrade and Reginaldo Arakaki, Polytechnic School of the University of São Paulo, Brazil.
Mo6_4	“Teaching an introductory course in soil mechanics using problem based learning: Scratching a Seven Year Itch” Declan Phillips and Michael Quilligan, University of Limerick, Ireland.
Mo6_5	“Technology and Intervention-Based Instruction for Improved Student Learning” Gaganpreet Sidhu and Seshasai Srinivasan, Queen's University, Canada.

Session Tu1: Teaching Quality and Evaluation
Time: Tuesday, August 26th, 10:00 am-11:40 am
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Paper Number	Title/Authors
Tu1_1	"Tuning Mechanical Engineering Higher Education in Africa toward Unified Quality and Accreditation" Samuel Mensah Sackey, Mohammad Megahed, Venkata Ramayya Ancha, Beatrice Delpouve, Charles Awono Onana, Raindandi Danwe, Moses Phinehas Mngwapa Chinyama, Shadreck Chama, Venant Kayibanda, Leonard Kabeya Mukeba, Nawaz Mahomed and André Müller, Kwame Nkrumah University of Science and Technology, Ghana.
Tu1_2	"Addressing Assessment and Grading in Engineering Education" Vidar Gynnild, Norwegian University of Science and Technology, Norway.
Tu1_3	"Experiences Teaching a Capstone Design Course" Susan J. Masten and Syed W. Haider, Michigan State University, United States of America.
Tu1_4	"University Wide Program Management for Quality Assurance of Undergraduate Research" Masahiro Inoue and Mano Kazunori, Shibaura Institute of Technology, Japan.
Tu1_5	"Additive Manufacturing in First Year Engineering Undergraduate Experiential Design" Thomas Doyle, McMaster University, Canada

Session Tu2: Teaching Approaches
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Tu2_2	"An Embedded Systems Curriculum Design Based on the Software-Hardware Co-Design Methodology" Ling Ming, Lei Wei, Tang Yongming and Shi Longxing, Southeast University, China.
Tu2_3	"Construction of Mental Models in the Minds of Engineering Technology Students" Timber Yuen, Dan Centea, Lucian Balan and Ishwar Singh, McMaster University, Canada.
Tu2_4	"Teaching Interdisciplinary Engineering and Science Educations" Lise Busk and Marian Stachowicz, Aalborg University, Denmark.
Tu2_5	"Video Games as a Pedagogical Tool for Teaching Computer Programming" Samantha Chan and Spencer Smith, McMaster University, Canada.

Session Tu3: Technology in Engineering Education
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Paper Number	Title/Authors
Tu3_1	"HOW STUDENTS USE MEDIA: A COMPARISON ACROSS FACULTIES" Gerd Gidion, Luiz Fernando Capretz, Ken Meadows and Michael Grosch, Karlsruhe Institute of Technology, Germany.
Tu3_2	"PSSE-Based Computer Simulation of Wind Farm Dynamic Performance by Undergraduate Engineering and Technology Students" Chi Tang, Joe Darocha and Matthew Bradica, McMaster University, Canada.
Tu3_3	"Importance of Human Computer Interaction (HCI) in Critical Success Factors (CSFs) of e-Learning" Asaf Varol and Naveed Ahmed, Firat University, Turkey.
Tu3_4	"Smartphone as a Learning Platform for Sensors and Measurement Technology" He Lingsong and Zhou Liping, Huazhong university of science and technology, China.
Tu3_5	"Enhancing Ethical Awareness though Practical Engagement with Mobile Media" Meriel Huggard and Ciaran Mc Goldrick, Trinity College Dublin, Ireland.

Session Tu4: Engineering Education around the World
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Tu4_2	"Reforming Mechanical Engineering Higher Education in Africa for Increased Industry Relevance" Samuel Mensah Sackey, Mohammad Megahed, Charles Awono Onana, Venkata Ramayya Ancha, Shadreck Chama, Moses Phinehas Mngwapa Chinyama, Raindandi Danwe, Beatrice Delpouve, Leonard Kabeya Mukeba, Venant Kayibanda, Nawaz Mahomed and André Müller, Kwame Nkrumah University of Science and Technology, Ghana.
Tu4_3	"International collaboration teaching method for Mechatronic Innovation Decision-making and Design Tools" Youmin Hu, Ling Ling, Thomas R. Kurfess, William Singhose and Bo Wu, Huazhong University Of Science and Technology, China.
Tu4_4	"Studies of Energy Use, Green IT Practices and the Role of Entrepreneurship in Higher Engineering Education in Nigeria" Olaitan Afolabi and James Uhomoibhi, Salem University Lokoja, Nigeria.
Tu4_5	"Technical Education: Past, Present, and Future" Yuko Hoshino and L Wayne Sanders, Tokyo University of Pharmacy and Life Sciences, Japan.

Session Tu5: Trends in Engineering Education II
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Tu5_2	“A Discussion on Some Simple but Effective Methods on Keeping A Large Group of Students Motivated to Learn any Engineering Subject” Quazi Rahman, University of Western Ontario, Canada.
Tu5_3	“Additive Manufacturing at a Distance: The Internet of Lab Things” Thomas E. Doyle, McMaster University, Canada.
Tu5_4	“"Big-Data" processing tool for students” Jimin Song, Dongjoo Kim, Hanwoo Kim and Hyunik Yang, Hanyang University, Korea.
Tu5_5	“SELECTING RESEARCH STAFF USING A MODIFIED BEHAVIOUR DESCRIPTION MODELLING (BDM) APPROACH” Nafia Al-Mutawaly and Michael W. Piczak, McMaster University, Canada.

Session Tu6: Design Education
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Tu6_1	"Problem & Project Based Learning: Preparing Students from developing Countries - A comparative Analysis -" Tomas Benz and Angella Musiimenta, Heilbronn University, Germany.
Tu6_2	"Implementing Reflective Writing in a Problem-Based Learning Civil Engineering Programme" Thomas Cosgrove, Terence Ryan and Darina Slattery, University of Limerick, Ireland.
Tu6_3	"Design and Validation of Leadership Education Integrating Simulation and Project Based Learning" Tomoko Maruyama and Masahiro Inoue, Shibaura Institute of Technology, Japan.
Tu6_4	"Facilitating Transformative Interdisciplinary Collaborative Projects: The IMPACT (Interdisciplinary, Meaningful, Practice, Applied, Community, Transformative) Project" Robert Fleisig, Lovaye Kajiura and Brenda Vrkljan, McMaster University, Canada.
Tu6_5	"Experiential Learning Paradigm Revisited" Vojislav Ilic, Yasmin Tolentino and Kimberley Vincent, University of Western Sydney, Australia.

A multidisciplinary module-based biotechnology lab course: forging bridges between Biochemistry and Chemical Engineering experiential-based learning

Felicia Vulcu*[1], Meagan Heirwegh[1], Kim S. Jones [2,3], and Rena M. Cornelius [3]
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***Abstract*— Engineering and science technologies are growing at an unprecedented rate, thus emphasizing the need to adapt the current curriculum to address expectations of ever-changing academic and industry stakeholders. The inception of fields such as biotechnology serves as an interface for multidisciplinary collaborations between biomedical sciences and engineering. In this milieu, both fields are equal partners that share their experiences and viewpoints towards the common goal of creating biomedically relevant products. Using the revised Bloom's taxonomy as a model for curriculum design, we created a multidisciplinary laboratory course for our students. This course encompasses three modules which span the gamut of current biotechnology. These modules include mammalian cell culturing, biomaterial testing and production of commercially relevant recombinant proteins utilizing bench-top bioreactors. The modules are designed to reflect a blended curriculum exploiting various pedagogies of engagement; from active learning to cookbook style labs. We propose that a blended pedagogy can successfully instil practical and transferrable skills to a multidisciplinary student body. To this end, we created a cookbook-based module entitled "biomaterials". However, emphasis is placed on collaborative learning and industry/ research techniques that promote student involvement and motivation. At the other spectrum we created an active learning module entitled "bioreactors". In this module, students experience group interdependence and collaborative skills as they develop a testable experimental procedure. We hope to increase critical thinking, project ownership and engagement. Our final module, entitled "tissue culture" utilizes a blend of inquiry and cookbook pedagogies. Our hope is that all three modules will be successful in creating an engaging environment for the students.**

Here we describe the current module-based course structure from the designers' perspective, including course design and student assessment. We further discuss the relevance of our blended pedagogy within the course structure with our future plans to assess student experience in the course.

Keywords*— *course development, inquiry, multidisciplinary, biotechnology, transferrable skills, critical thinking, engagement;

I. INTRODUCTION

Today's knowledge-based economy is driven by constant (bio)technological advancements. Consequently, the discipline-specific academic skills once coveted by our graduating students have been replaced by a gamut of workplace defined skills dictated by industry and academic stakeholders [1]. Numerous published articles, from various disciplines, have dubbed this technological change as the new "revolution" [2], or "golden age" [3]. Learning for such an unknown future [4] brings forth innumerable challenges for the university and its role as a teaching-research-entrepreneurial institution [5]. One commonality within these publications is the disconnect that exists at the curriculum level between the entrepreneurial impetus and the traditional, compartmentalized disciplinary structures (i.e. separate faculties and departments) [6] The pedagogical field has certainly risen to this insurmountable task by constantly evolving teaching and learning styles to meet stakeholder demands [7]. One answer to this disconnect is the concept of "convergence" in the biomedical sciences [8]. Convergence applies to multidisciplinary (science and engineering) collaborations; the establishment of new opportunities to benefit society. In this vein we created a platform for allowing free exchange of ideas between two different student bodies that are regarded as equals. The new opportunity is the challenge faced by biotechnology to deliver biomedically relevant products in various fields: from biomaterial design, recombinant protein expression, tissue engineering, etc. [9].

Driven by the principle of convergence a collaboration was forged between the departments of Biochemistry & Biomedical Sciences (BBS) and Chemical Engineering (CE) to create a module-based laboratory course. Given the multidisciplinary nature of this course, we first recognized the diversity in learning styles between these two faculties [10] and applied a custom-tailored pedagogy to meet our specific needs. Tapping into the vast pedagogical literature, we chose to build upon the revised Bloom's taxonomy (cognitive domain) as we felt it fulfills our educational goals and emphasizes both retention and transfer of learned processes [11]. Briefly, the revised taxonomy is divided into 6 hierarchical cognitive process categories: remembering (R), understanding (U), applying (Ap), analyzing (An), evaluating (E) and creating (C). The revised taxonomy also highlights our goal of meaningful learning, which promotes cognitive transfer of the retained material such that it can be applied to new problems [12].

In this article, we describe the course blueprint from the perspective of the course designers. Particular emphasis is placed on module lab content and goals, assessment of desired student learning outcomes and future considerations in course development.

II. COURSE DESIGN

Given our perceived notion of learning as an interexchange between both cognitive and non-cognitive factors [13], we set out to develop a laboratory course that aims to interconnect the academic content with students' skills, attitudes, and motivations required in the field of biotechnology. The overall course design is highlighted in Figure 1, and entails 2 bookends (prelude and postlude) that flank the 10-week lab course.

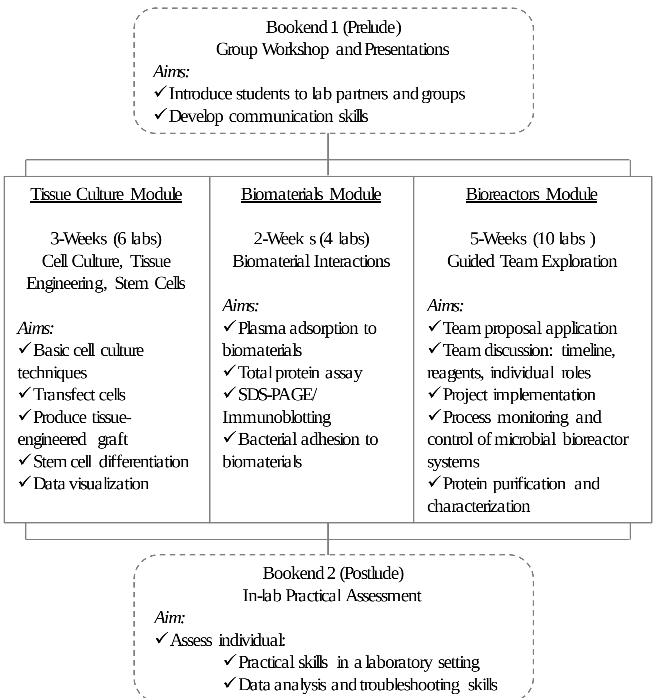

Figure 1: Description of 4LL3 course content and aims.

The course is further divided into 3 modules: Tissue Culture (TC), Biomaterials (BM) and Bioreactors (BR). The prelude serves the dual purpose of actively engaging students with the course layout and facilitating collaborations between students from both faculties (Table 1). Students are initially divided into 3 groups that cycle between the 3 modules throughout the course. Within each group, students are paired; usually one BBS student with one CE student, thus fortifying the main drivers of convergence theory. The opening workshop tasks students to work as a group and, with facilitation from their Teaching Assistant (TA) and course designers, compile a concept map encompassing the main ideas from their starting module. This activity not only promotes collaborative skills, but also serves to allow students a more in-depth understanding of their first module. Presentations follow the workshop component in which a two-tier system has been implemented: each group must present their specific module concept map, but within each group students are tasked with breaking down and presenting the concept map as a pair.

Table 1: Brief description of desired learning outcomes, assessments and classification of concepts introduced in the prelude and postlude bookends. (Remembering (R), Understanding (U), Applying (Ap), Analyzing (An), Evaluating (E), Creating (C))

Desired learning outcomes	Assessment	Classification (revised taxonomy)
PRELUDE		
Collaborative learning[14]	Group and pair: Concept maps[15] Presentation & peer review	1-R 2-U 4-An 5-E
Social skills, verbal communication		
POSTLUDE		
Individual critical data analysis	In-lab practical (protein assay) and data analysis	1-R 2-U 3-Ap 4-An 5-E
Individual technical skills	In-lab practical (cell culture and protein assays)	1-R 2-U 3-Ap 5-E 6-C
Time management, optimism, grit		N/A

The pair presentations must flow in a cohesive manner. When not presenting, each group critically reviews and asks questions of another group's presentation. We feel this assessment style encompasses not only collaborative skills, but also non-cognitive factors such as social skills, verbal communication, emotional maturity, curiosity, optimism, zest, grit and interpersonal skills [13]. Contrary to the prelude, the postlude assesses individual learning (Table 1). This is accomplished through a two part in-lab practical engaging individual students in time-sensitive applications of tissue culture and protein assay techniques. This assessment is extremely useful as it allows us to see the extent of knowledge transfer to the student in the most practical sense. It also allows us a glimpse into the development of the student's other skills such as time management, optimism, perseverance, stress management, etc.

A. *Tissue Culture Module (blended traditional cookbook and collaborative learning)*

The tissue culture module spans 3 weeks (8 hours/week) and is aimed at exposing students to basic technical skills of mammalian cell culture and genetic engineering within the context of biotechnology. Whilst this module is primarily taught using traditional "cookbook" protocols, week 2 of the module allows students to apply their understanding of cell culture technique by optimizing and testing a transfection protocol. Critical thinking and collaborative learning play a major role in designing this pair-wise protocol. Despite the traditional nature of the protocols, students approach the experiments with tremendous enthusiasm and eagerness. We believe this is due to multiple reasons including student interactions, real-world topic relevance and the immediate gratification obtained from photographically visualizing results. Continuous student interactions allow for practical transfer of knowledge between participants embodying various scientific viewpoints. The TAs serve the dual purpose of nurturing the learning process and conveying their graduate research experiences providing real-world topic relevance to the students. Tissue culture TAs are typically recruited from the McMaster University's Stem Cell and Cancer Research Institute and the School of Biomedical Engineering. Lastly, and perhaps most importantly, we suspect that the student enthusiasm in this module is largely attributed to the use of microscopy to visualize data, and a camera to capture the results. This provides students with an immediate, tangible and vibrant product they can reflect upon. We constantly witness the pride and exuberance students display at the microscope station.

Table 2: Tissue culture module: desired learning outcomes, assessments and classification of concepts.

Desired learning outcomes	Assessment	Classification (revised taxonomy)
TISSUE CULTURE MODULE		
Collaborative learning: communication	Pair lab report	1-R 3-Ap 5-E 2-U 4-An 6-C
Visualizing Data		Engagement Taxonomy [16]
Critical thinking	Protocol optimization	1-R 4-An 2-U 6-C
Technical knowledge and skill acquisition	Lab notebook, prelabs, quiz	1-R 3-Ap 5-E 2-U 4-An
	Lab practical (cell culture)	1-R 2-U 3-Ap

Student assessment throughout this module is multifaceted and includes lab notebooks and participation as well as a pop quiz, a final report written as a pair collaboration and an individual in-lab practical test (Table 2). We would like to focus our discussion on the impact of the pair lab report and the lab practical. Moreover, students are not penalized for generating less than optimal results, provided they can speculate where they might have gone wrong and how they might improve their results in the future. The pair lab report is an opportunity for students to develop not only their critical thinking skills, but also their collaborative skills as they must work together in order to create a written assessment of their results in the context of real world applications. Combined with the data visualization piece, students transcend their knowledge transfer to the “engagement taxonomy” [16]. Simply put; students have a more positive and engaging experience through their exposure to instant visualized results from their cell culture experiments. The tissue culture portion of the in-lab practical test assesses the depth of individual learning through application of knowledge acquired throughout the course. This is accomplished by evaluating the student’s ability to plan and execute a brief experiment in a limited time frame, while ensuring that proper aseptic techniques and safety considerations are followed. The results from this assessment show that the majority of the students in the section (79% class mean, 80% median) have developed enough of an understanding of the techniques used in this section to successfully execute an experiment, with no guidance, under time pressure. In conclusion, the use of blended learning styles – including cookbook protocols – has successfully allowed us to create a module fit for our specific course needs. We are looking forward to qualitatively assessing this success from the student viewpoint.

B. Biomaterials Module (cookbook lab with industrial applications)

The Biomaterials module is concentrated in 2 weeks (8 hours/week) and serves a dual purpose: introduce students to fundamental biochemical techniques, and engage students in biomaterial testing and industry. Biomaterials, as a means for improving biomedicine, have certainly become a multi-billion dollar industry; metals, polymers and ceramics play a major role in implants and medical devices [17]. This module relies heavily on cookbook-style protocols to mimic the real-world industry applications with respect to biomaterial standard testing (i.e. ASTM). Students work together in groups of two throughout the module. The group size is optimal for this module as it is small enough to allow each student the opportunity to become proficient in the techniques while sharing the work with a partner. The report for this section is an individual, formal laboratory report (Table 3). The nature of the assessment guides students to think about what they did, why they did it and how their work fits into the field of biomaterials as a whole. Interpretation of the results is often a challenge for the students as unsuccessful or unexpected results are not uncommon. We have already encountered visible exasperation among students, who have difficulty explaining the results or understanding the significance of the section as they may not see the benefit of using one biomaterial over another. This may suggest that in a cookbook style module, where students are given step-by-step instructions, there is an expectation of success that is not found in modules with even small inquiry components. The students may expect that the experiments have been optimized and set up for their success. Increasing student ownership of their results can be explored by requiring the students to critically analyze and report their findings in a short letter to the company providing the test biomaterials.

Table 3: Biomaterials module: desired learning outcomes, assessments and classification of concepts.

Desired learning outcomes	Assessment	Classification (revised taxonomy)
BIOMATERIALS MODULE		
Technical knowledge and skill acquisition	Lab notebook, prelabs, pop quiz Lab practical:protein assay	1-R 3-Ap 5-E 2-U 4-An
Critical thinking Data analysis	Individual lab report	1-R 3-Ap 5-E 2-U 4-An 6-C
Industrial application	Evaluating biomaterials Written experimental outcomes	1-R 4-An 6-C 2-U 5-E

C. *Bioreactors Module (inquiry-based laboratory module)*

Group experiential learning is at the core of this module intended to elicit an authentic research-design experience. This is accomplished by immersing students in an investigative scenario and asking them to develop and test an experimental plan. Students are allotted tremendous latitude in their project design and proposed experiments. Additionally, students are provided with a number of resources: from courseware to external company handbooks and manuals posted on Avenue2Learn. The BR module spans 5 weeks (8 hours/week) and involves groups of 8-10 students. We have already determined that this group size is not optimal as groups tend to fall into a number of performance pitfalls including: social loafing, the Abilene paradox and uneven distribution of labour

[18]. Left unchecked, this may result in lower levels of engagement and ownership of the project than would be expected from an inquiry based lab. Given that group size is a fine balance between the complexities of the task, available resources, time limitations and member involvement, future iterations will include a more optimal group size of 4-5 [19]. Additionally, increasing group cohesiveness and focusing on individual and personal involvement also play a major role in increasing group efficiency, productivity and overall learning [20]. We assess individual involvement through weekly lab participation and preparedness marks, although we plan to implement self/ peer assessment and reflection to capture the student viewpoint throughout this experience.

Assessment also encompasses a group grant proposal at the beginning and an individual grant renewal at the end of the module (Table 4). The group grant proposal is formulated in-lab using round-table discussions and chalk talk. Students are given latitude to develop their proposal, with ample input from course facilitators, in a safe space fitting for idea generation. This is especially important from the perspective of convergence as it allows students with a variety of educational backgrounds to equally contribute their expertise to the problem at hand. At the conclusion of the module students submit an individual report written as a grant renewal. The individual nature of this report is paramount in emphasizing the importance of the student's unique input to the group project. Additionally, both of these written compilations serve to underscore troubleshooting and critical thinking skills with respect to project design and group collaboration.

We are very proud of this module and we look forward to enhancing group interactions and student input in the future.

Table 4: Bioreactors module: desired learning outcomes, assessments and classification of concepts.

Desired learning outcomes	Assessment	Classification (revised taxonomy)
BIOREACTORS MODULE		
Technical knowledge and skills	Lab notebook	1-R 2-U 4-An 5-E
	Lab practical:protein assay	1-R 2-U 3-Ap 4-An 5-E
Critical thinking Data analysis	Individual grant renewal	1-R 2-U 3-Ap 4-An 5-E 6-C
Development and execution of research plan	Group grant proposal Group discussions Individual grant renewal	1-R 2-U 3-Ap 4 - An 5-E 6-C
Group engagement	Group grant proposal In-lab group discussions	N/A

III. FUTURE INSIGHTS

Using the model for experiential learning, and current literature, we developed stronger module foundations in this multidisciplinary course. The impetus for such metamorphosis stems from our realization that the word "stakeholders" also encompasses our students. Their personal learning journey must be considered in the course design. Students should be actively engaged not only in the module content, but also in our continual adaptation of the course. As such, we plan to engage our students in their own learning process by conducting a comprehensive assessment of student experience in each module and allowing students' input in design of their course syllabus. Using this student-engaged strategy, we hope to inspire team collaboration, project ownership and biotechnology-driven entrepreneurship. We will publish the student viewpoint of this course in the near future.

ACKNOWLEDGMENT

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Development of Traditional Skill and Technology Learning Method Using Digital Tools

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***Abstract*—Succession of the traditional skill and technique requires the relationship between master and apprentice. Master shows the skill and technique, and apprentice learns through repeating of practice for a long time. In Japan, although many local special traditional skills exist in many places, it became difficult to preserve and succeed the traditional skill, because of aging of these masters and shortage of successors in recent years.**

In this study, a new learning method of traditional skills is developed by using data based on the multimedia. Japanese wooden ship "Tsunoshima-denma" ship was selected as the subject. The wooden ship can be made by same way on 3D-CAD with actual fabrication. The process of shipbuilding can be preserved as history tree by function of 3D-CAD. In this way, preservation and succession of traditional skill and technique will be able to be achieved by new learning method proposed here using 3D-CAD.

Firstly, 1/12-scale model was made after the shipbuilding process had been understood by documents and video movies of master's work. The process of making the scale model imitates actual procedure as much as possible. Secondly, "Tsunoshima-denma" ship is assembled on 3D-CAD. Each part of the ship were modeled and assembled in the similar way of the actual processes and dimensions. Finally, we tried to make database of learning method with HTML format which helps apprentice to understand the shipbuilding method and process.

We understood the actual shipbuilding deeply, and experienced how difficult the process is, and how long time is needed to make it by making scale model. Reproducing of "Tsunoshima-denma" ship in the similar way with actual procedure on 3D-CAD is very important and effective for succession of traditional production skill. Adding of explanations and movies about the shipbuilding to the database as much as possible, preservation and succession of the traditional skill will be established, and new learning method will be achieved.

Keywords- traditional skill, succession and preservation, digital tools, multimedia

I. INTRODUCTION

Succession of the skills and techniques is very important in various fields. In Japan, a lot of special traditional skills which should be succeeded exist in many places. Although the relationship between the master and apprentice is necessary for succession of skills and techniques, however, aging of these masters and shortage of successors became serious problem. Recently, succession of the skills and techniques is becoming difficult. Therefore, it is needed to be converted to datum with objectivity and reproducibility [1]. We propose the new preservation method by using datum based on multimedia. In this study, multimedia means document, sketch, drawing, photograph, movie, voice, sound, and 3D-CAD; as a new medium. Fig. 1 shows the conceptual diagram of this study.

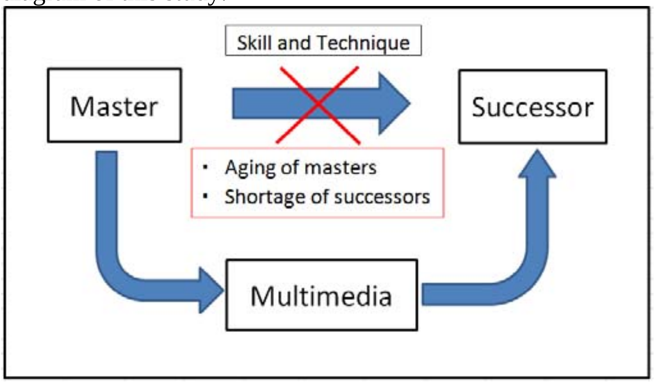


Fig. 1 Conceptual diagram

II. PROCEDURE OF RESEARCH

The purpose of this research is developing a new preservation and learning method of skill by using datum based on multimedia. After having understood of the shipbuilding process by existing documents and video movies, we tried to make database which helps apprentice to understand the method and process. In this study, "multimedia" means document, sketch, photograph, movie, sound, voice, 3D-CAD and so on.

Fig. 2 “Tsunoshima-denma” ship

Japanese wooden ship "Tsunoshima-denma" ship was selected as the subject. Fig. 2 shows "Tsunoshima-denma" ship. This ship is used for gathering of marine product in shallows. Although it is made by traditional skill and technique existed in Yamaguchi prefecture, the method of shipbuilding is becoming extinct in recent years.

From 2002 to 2003, "Tsunoshima-denma" ship was reproduced by an shipbuilder in Hohoku-town of Yamaguchi prefecture as a town event. In the shipbuilding, all processes were carefully observed and recorded by many staff for six months. The amount of recorded media is video tapes of 141 hours, 173 pages of notebooks including documents and sketches, great number of photographs. Then introducing digest video DVD [2] and 197 pages of report [3] were published by Hohoku-town. We decided to use these media materials to develop the preserving and learning method.

In the development, firstly, original size drawings were edited. Secondly, 1/12 scale model was made as training and for understanding of shipbuilding processes and methods. Next, ship was modeled and assembled on 3D-CAD in the similar way of the actual processes and dimensions. Finally, all of media datum was edited in HTML format as the database for preserving and learning materials.

III. Development of Learning Method

A. *Editing of original size drawing data*

Fig. 3 shows the name of main parts of the ship. It can be seen in this photo, some parts of the ship are bended to make these shapes.

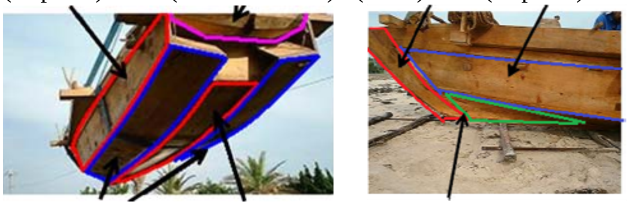
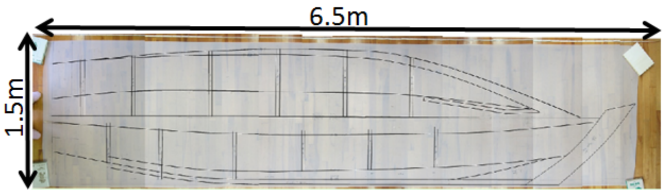
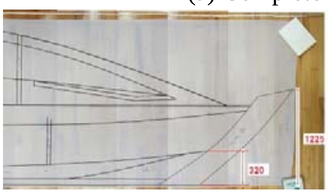


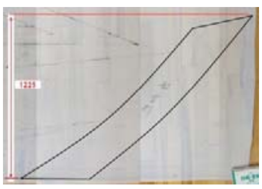
Fig. 3 Name of parts



(a) Complete edited data



(b) Front region



(c) Prow

Fig. 4 Editing of original size drawing

Firstly, it is necessary to know each size of the ship. Before actual shipbuilding, original size drawings were made, and those drawings still exist. Because of too large drawing (about 1.5×6.5m), it taken as several pieces of photographs and were connected by using computer software. In addition, the lines of the original size drawing were traced as clearly seen on the software. Fig. 4 represents editing of the drawing data. Fig. 4(a) is complete edited data. The upper of the photograph is the top view of the ship, and the lower shows the side view of the ship. After editing, this drawing is separated for every region like Fig. 4(b), for easy handling in the database. Fig. 4(b) shows the front part of the ship, and Fig. 4(c) is a drawing of the stem called Miyoshi.

B. *Fabrication of scale model*

The purpose of making scale model is to understand the process and method of shipbuilding. After understanding of the process of shipbuilding by documents and video movies, 1/12-scale model was fabricated in the similar way with actual procedure. Table 1 shows the procedure of scale model. In fabrication of scale model, we reproduce until assembling Uwadana. Uwadana is topside of the ship. The material is balsa wood, and tools used for making were cutter knife, abrasive paper and woodworking adhesive. Fig. 5 shows steps of making of scale model. As shown here, the processes of the scale model imitated actual procedure as much as possible. Fig. 6 shows bending process by hot steam in actual shipbuilding. In the making of 1/12-scale model, the parts were bended by dunking into boiling hot water. Fig. 7 shows 1/12-scale model.

Table I: procedure of scale model

①	Making Kawara (Keel)
②	Bending Kawara
③	Making Miyoshi (Stem)
④	Assembling Miyoshi
⑤	Assembling Sangai (Reinforcing material)
⑥	Assembling Nakadana (Bottom)
⑦	Assembling Todate (Transom)
⑧	Assembling Uwadana (Topside)

(a) Assembling Sangai

(b) Making Todate (Transom)

Fig. 5 Making process
(Left: Scale model Right: Actual making)

Fig. 6 Bending of wood plate

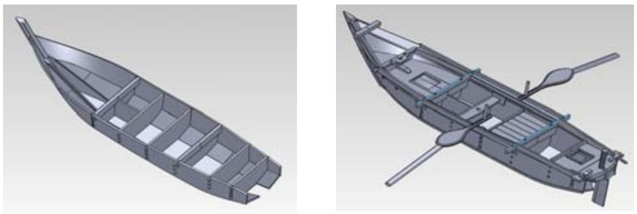
Fig. 7 Scale model

C. Modeling on 3D-CAD

Preservation of traditional skill using digital data is important. Therefore, each part of the ship were modeled and assembled in the similar way of the actual processes and dimensions. SolidWorks(TM) was used in this study. The sizes of each parts were decided by original drawing, and real ship dimensions measured by former researcher [4]. Fig. 8 shows an example of assembling parts. Fig.8 (a) is the keel called Kawara. Fig.8 (b) and (c) show assembling of other parts into Kawara. In ordinary way using 3D-CAD, all parts are assembled after each parts modeling. But this way is not satisfy our purpose. We made 3D model as shown in Fig. 8, parts modeling and assembling were simultaneously performed like real making processes.

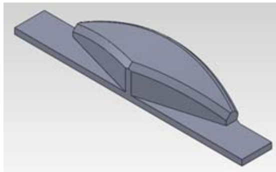
(a) (b) (c)

Fig. 8 Assembling

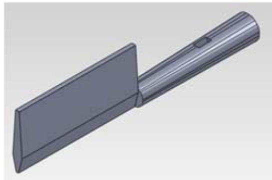


(a) Scale model (b) Completed scale model

Fig. 9 3D-CAD model

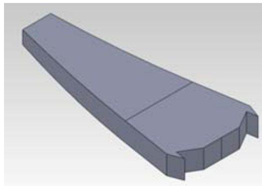


Toko (Rudder holder)



Kaii (Rudder)

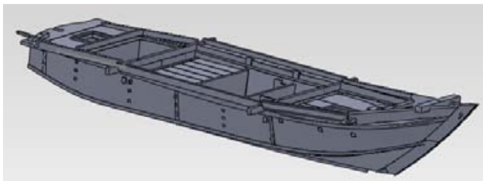
Ro (Oar)



Osiage (Slider)

Fig. 10 Parts for fishery functions

(a) Actual ship



(b) 3D-CAD model

Fig. 11 Actual ship and 3D-CAD model

Fig. 9 shows 3D-CAD model. Fig. 9 (a) is the model of basic ship function which can float on the water as same as scale model makeing, and (b) shows the complete model has all parts for fishery functions, and also has oar and rudder. Fig. 10 show fishery function. These parts are assembled to decide position and course of the ship. Assembling these parts, "Tsunoshima-denma" ship has the function gathering marine product in shallows.

Fig. 11 shows the actual "Tsunoshima-denma" ship and assembled 3D-CAD model. As seen here, some differences occur between the real ship and the 3D-CAD model, especially front part of the ship. These differences were caused from the fact that there was no design drawing with correct dimensions. To prevent these differences, accuracy measuring of shape and dimensions of ship's parts is important.

D. EDITING LEARNING MATERIAL

The learning database about the process and method of shipbuilding was expressed by using HTML format. This database, including original size drawing data, can help apprentice (successor) to understand size and shape of the ship. Fig. 12 is the top page of the learning materials.

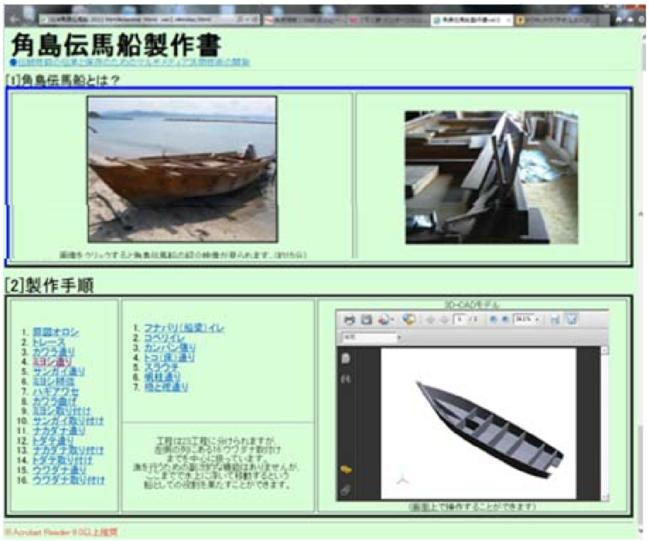


Fig. 12 Top page of HTML database

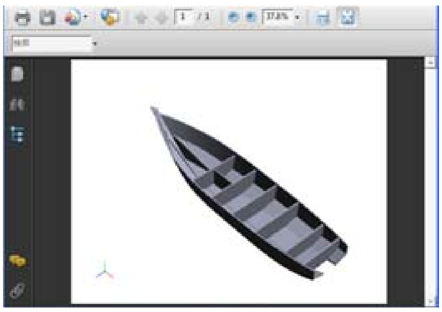


Fig. 13 3D-PDF model

Fig. 12 shows the database, which consist of multimedia datum. This database includes 3D-CAD model's data. Clicking these pictures, the detail data to understand shipbuilding process (document, movie, photograph, etc. and 3D-PDF model and 3D-CAD data) is shown on the display. Fig. 13 shows the 3D-PDF model made from 3D-CAD data. We can operate and change the ship angle on screen and can imagine the shape of the ship. In this database, the history of 3D-CAD model is included like Fig. 14. The right side of the picture is history function of 3D-CAD. It is very important in this proposed learning process that the successor can learn shipbuilding process by using of this history tree.

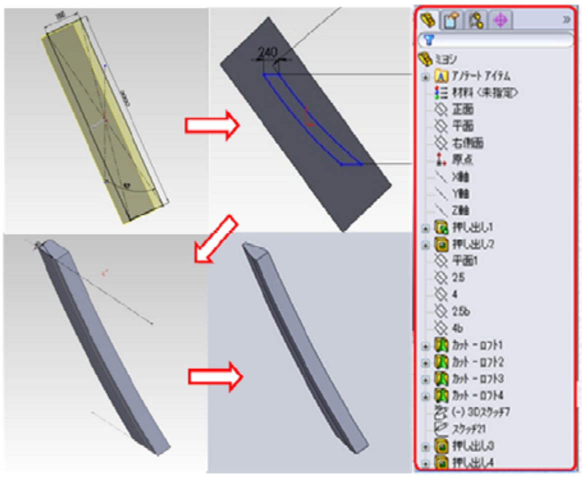


Fig. 14 History of 3D-CAD

IV. CONCLUSIONS

We understood the actual shipbuilding deeply, by fabrication of the 1/12 scale model. In spite of making only a scale model, we experienced how difficult the process is, and how long time is needed to make it. Since producing of real size ship needs much time and materials, making scale model is economical way to understand shipbuilding process.

On the other hand, 3D-CAD modeling of "Tsunoshima-denma" ship in the similar way with actual procedure is very important. Especially using the history function of 3D-CAD is much effective to understand the processes. Now, preserving shipbuilding process on the computer has been almost achieved. Finally, the new preserving method and learning material of traditional skill and technique proposed here will be expected to be able to apply effectively to other many fields.

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Teaching Integrated System Design: Case of Mechatronics Project based on a Line-Following Robot

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Abstract—Automation systems are generally made up of three main components, namely software, electronics/electrical and mechanical subsystems. The interactions among these components affect the integrated system in terms of reliability, quality, scalability, and cost. Therefore, it is imperative that the three components of automation systems are designed concurrently through a system design paradigm generally referred to in literature as mechatronics. In this paper we present a mechatronics project used to teach integrated design in the Industrial Controllers and Networks course, in the Bachelor of Technology program at McMaster University. In this project, students work in groups of three or four people to design and implement a line following robot that is capable of turning around when the line terminates. The robot has wheels and main body which make up its mechanical system. In addition, it has a power supply, microcontroller, motors, and line-sensors all of which are integrated into its electronics/electrical subsystem. Finally, the robot has software that controls its mechanical and electronics/electrical subsystems.

Keywords—Automation-systems, robot, mechatronics, teaching-design, concurrent-design;

I. INTRODUCTION

In 1969, a senior engineer of Yaskawa, a Japanese company, introduced the word mechatronics to describe systems that use electronics to control mechanical components [2, 3]. Over the years, the definition of mechatronics has involved, and currently, it is used to mean the design, selection, analysis and control of system that integrate mechanical elements with electronic and software components [3]. This definition encompasses automated systems, making it appropriate to teach mechatronics principles in the Industrial Controllers and Networks course, in the Bachelor of Technology program at McMaster University.

It is generally agreed in literature that industry demands for new engineering graduates who have a strong multi-disciplinary background [4]. Fortunately, mechatronics is one of the few disciplines that are intrinsically multi-disciplinary. This makes it a good candidate for group based learning. In fact, group projects are an integral part of undergraduate mechatronics courses [5]. Through these groups, students are able to develop both practical and theoretical understanding of the course material. Moreover, they develop the interpersonal and communication skills necessary to work in the modern workplace [1]. In our course, we first cover the material used in the mechatronics project through lectures. These lectures include small group discussions, class quizzes as well as take home assignments. Thereafter student do laboratory work in which the lecture material is applied. The mechatronics project focuses on microcontroller programming, interfacing of microcontroller with sensors and actuators, as well as the mechanical integration of system components. Moreover, the project is used to strengthen students' knowledge in circuit analysis and design, a topic that is covered earlier in another course in the Bachelor of Technology program at McMaster University. In that project, students working in groups of 3 or 4 optimize the design, build and then test a small robot that uses autonomous control to follow a black line ¾ inches wide, drawn on white background course.

The rest of this paper is arranged as follows: In Section II we present the background of our mechatronics project and in Section III we present a description of the robotic car used in the project. In Section IV we discuss the design of the robotic car. Finally, the conclusion and future work is covered in Section V.

II. BACKGROUND

Mechatronics involves concurrent design and implementation of mechanical, electronics/electrical and software systems of an integrated system. The concurrent design and implementation process is necessary because the interaction among the mechanical, electronics/electrical and software systems affect the integrated system in terms of reliability, quality, scalability, and cost [3]. A mechatronic system can also be decomposed into hardware and software components. Figure 1 shows the hardware components of a mechatronics system, while Figure 2 shows the software representation of a mechatronics system.

A. Hardware

The mechanical system is the main component of a mechatronics system (see Figure 1), because it is the system that needs to be controlled. Such as a system may be a cutting tool of a CNC machine, an automated scale of a packaging machine, or a vehicle cruise control system [2]. The controller gets information about the state of the mechanical system from sensors. Since the sensors and controller may have differing input/output electrical characteristics, interfaces may be used to interconnect them. A similar situation exists between the controller and the actuators that are used to change the state of the mechanical system based on the controller commands. Note that the controller is the brain of a mechatronics system. It integrates user inputs and sensor information to generate actuator commands based on the stored user program.

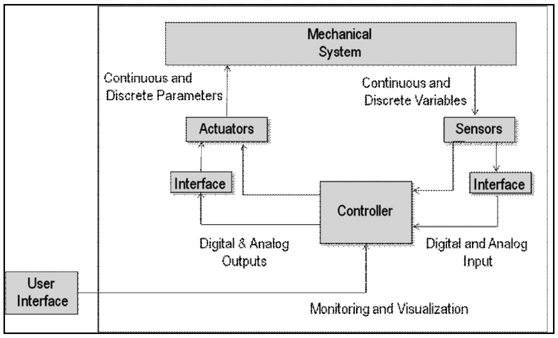

Figure 1: Hardware view of mechatronics systems

B. *Software*

From the software point of view, the knowledge representation system is the main component of a mechatronics system (see Figure 2). It utilizes the user and sensor data to generate information that is used by the decision making component to issue commands to actuators. The type of data received from the sensors, as well as the nature of commands expected by the actuator affect the software design. Hence the need to concurrently design the software and hardware systems through the mechatronics design paradigm.

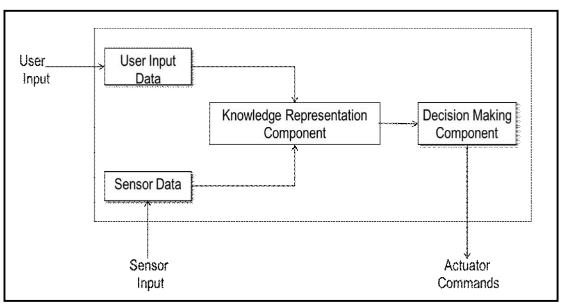

Figure 2: Software view of mechatronics systems

III. Design and Implementation

The focus of the mechatronics design project of the Industrial Controllers and Networks course, in the Bachelor of Technology program at McMaster University is to optimize the design of a robotic car that follows a line, and to build and test the robot. Therefore, students working in groups of 3 or 4 are given a kit of the major components of the robot, including: the microcontroller, DC motors, wheels, DC motor drives, and a solid works file of the robot main body or a 3D print body of the robot. On the other hand, the students are not given resistors and other components required to limit sub-circuit currents and set different reference voltage levels of the robot electronics/electrical circuit. Moreover, the students are allowed to switch out some of the project components within a given a cost limit.

Once all the mechanical and electronics/electrical components have been integrated, students program the robot according to control strategy developed during the design optimization process.

A. *Mechanical System*

The mechanical system that needs to be controlled in this project is the main body of the robotic car and its wheels, as well as the claw that picks objects placed on the line track. The main body of the robot has to be designed to have mountings for the claw, microcontroller, sensors, actuators and the power source. Figure 3 shows the 3D printed body of the robot with the electronics/electrical components already mounted onto it (robot hardware). Moreover, the figure shows the robot claw, as well as the conceptual design of the robotic. Note that students can modify this body to accommodate any components changes that they may make.

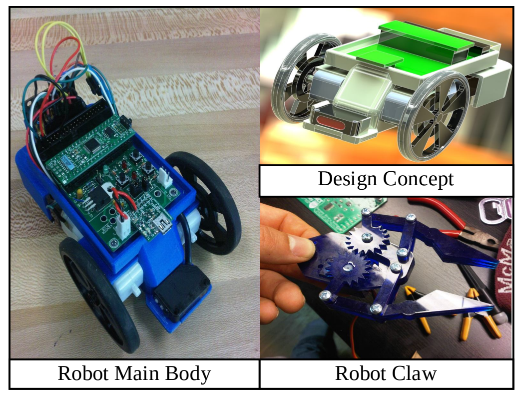

Figure 3: Robot Hardware

Figure 4 shows a modified version of the robot that is modified to accommodate both object and line sensors

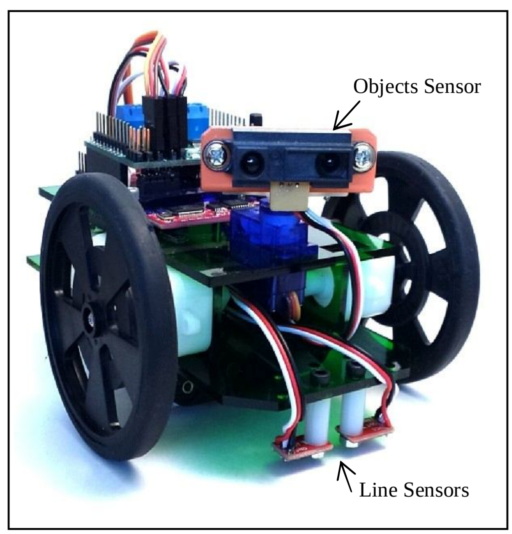

Figure 4: Robot with object and line sensors

B. *Electronics/Electrical System*

The electronics/electrical system consist of the microcontroller, object and line sensors, motors, motor drives, and the power sources. Figure 5 shows how a motor is connected to the L293D motor drive. The two command signals from the microcontroller are used to control the direction of rotation of the motor and to start/stop the motor. If one of the signals is high, the motor rotates in one direction, and if both signals are low or high, the motor stops

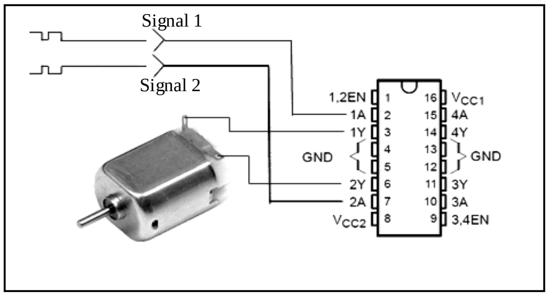

Figure 5: DC motor and motor drive

Figure 6 shows the entire circuit diagram of the robotic car electronics/electrical system. From the figure, it can be noticed that a power source of 9V powers the motor and the motor drive. But the microcontroller and the sensors are power through 9/3.3V voltage regulator. The figure also shows resistors used to limit currents in sub-circuits and to provide various reference voltage levels. Furthermore, Figure 6 shows that the turning action of the motor is achieved by either slowing down or stopping one of the motors, using motor drive L293D control signal I1 for one of the motors and I4 for the other. For fast turning, one of the motors could be reversed using motor drive L293D control signal I2 for one of the motors and I3 for the other.

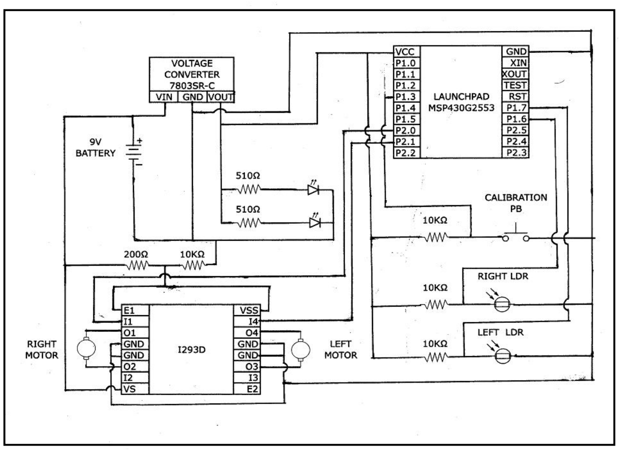

Figure 6: Robot circuit diagram

C. *Software System*

Just described in Section IIB, the software system of our robot has three main components, namely: user input and sensor data component, knowledge representation component and decision making component

User input and sensor data component: This component is represented by the variables that store user input and sensor data. These variables as well as their type have to be declared in the software so that the controller can reserve memory for them. For example in our robot we have to declare two variables of type Boolean. One stores user input data for starting and stopping the robot, while the other stores the presence or absence of an obstacle in the robot track. Moreover, we have to declare two variable of type Integer that store the color of the surface under each of the two line sensors (see Figure 4).

Knowledge representation component: This is the component that stores the meaning of the various combinations of states of the user input data and the sensor data. While there are many knowledge representation methods in literature, we use rule based knowledge representation in our robot. Column two of Table 1 shows some example of knowledge rules of the robot. Note that the discussion of knowledge representation is beyond the scope of this paper.

Decision making component: This component utilizes the meanings of the current combinations of user and sensor data derived by the knowledge representation component to issue commands to actuators that change the state of the mechanical system. The state of the system is changed in such a way as to achieve the system objective, which in this case is to follow a line and to remove objects on the robot track. Column three of Table 1 shows some examples of the decisions made by our robot based on the knowledge in column two.

Table 1: Knowledge Representation, Decision Making and Pseudo Code Examples

No.	Knowledge Representation	Decision	Pseudo Code
1.	IF left line sensor is over white board and right line sensor is over black line, THEN the robot car is getting off the line towards the left	IF robot is getting off line towards left, THEN stop or right motor	IF (*LeftSensorColor* = *Whiteboard* && *RightSensorColor* = *BlakLine*) { *LeftMotor* = ON; *RightMotor* = OFF; End IF; }
2.	IF both line sensors are over the black line, THEN the robot car is moving in the direction of the line	IF the robot car is moving in the direction of the line, THEN keep both motors running	IF (*LeftSensorColor* = *BlackLine* && *RightSensorColor* = *BlakLine*) { *LeftMoto*r = ON; *RightMotor* = ON; End IF; }

Note that in some cases the knowledge representation and the decision making components are integrated to form "IF" statements in the software application. Column 4 of Table 1 shows the pseudo code of the combined knowledge representation and decision making.

IV. Discussion

We have done this project for the last four intakes because it is the basis of our laboratory-based learning model in the course, Industrial Controllers and Networks, in the Bachelor of Technology program at McMaster University. Every other year we change the microcontroller. Furthermore, we give the CAD file of the robot body to students to modify the design if they wish; and over the years, students have always made many changes to the entire design. For example, they select different sensors, motor drives, and power supplies. Consequently, they have to change the mechanical design of the robot body, and have to use different algorithms in their robot control programs. Moreover, students implement additional features that may earn them extra credit.

In this section we present some of the observations that we have noted about our mechatronics project. The observation clearly prove that a given software design for automated systems works well only for specific mechanical and electronics/electrical designs. This is caused by the level of interaction among these systems, hence warranting the use of the concurrent design paradigm of mechatronics. Moreover, this justifies the teaching of concurrent or integrated system design in the Industrial Controllers and Networks course, in the Bachelor of Technology program at McMaster University.

Observation 1: Our robot was designed to have two line sensors both have to be directly above the black line when the robot is moving in the direction of the line (see Table 1). As the robot starts to move in a different direction from that of the line, one of the sensors goes directly above the white board, and a decision is made to slow or stop one of the motors in such as a way as to bring both the sensors onto the line. This makes the robot to turn in the direction of line. If we had designed the robot to have two line sensors mounted directly above the white board with the black line sandwiched between them; or if the robot had a single line sensor; the knowledge representation and the decision making process would have been different.

Observation 2: Our robot turns by stopping one of the motors. If the robot had been designed to make smooth turns by slowing down the motors, or designed to turn fast by reversing one of the motors, the actuator commands as well as the electronics/electrical system would have been different.

Observation 3: The color under the line sensors can either be white: the color of the board on which the line is drawn, or black: the color of the line. Therefore, with the use of appropriate sensors or sensor/controller interface, the sensor data can be type Boolean. This has a profound effect on memory use since Boolean data type requires one bit of storage per variable while Integer data type requires two bytes per variable. This shows the relationship between the electronics/electrical design and software design, and hence the need to carry them out concurrently.

V. CONCLUSION

In this paper we discuss the need to teach a design paradigm the supports the concurrent design of mechanical, electronics/electrical and software components of automated systems such as robots. Such a paradigm is generally referred to in literature as mechatronics. Moreover we describe a mechatronics project carried out in the course, Industrial Controllers and Networks in the Bachelor of Technology program at McMaster University. In the future we would like to integrate a pick and place robot with our robotic car. We hope to have two groups collaborate in this project, where one group would focus on the pick and place robot and the other group would focus on the robotic car. Thereafter the two groups would integrate the robots to form a single pick and place line following robot.

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Teaching Electromagnetics through a Combination of Blended Learning and Experiential Learning

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***Abstract*—I present in this paper overview of an experiment that was carried out at McMaster University, Canada on teaching electromagnetics. A combination of experiential learning and blended learning was used at an introductory electromagnetics course. The results show improvement in the way students rated both the instructor and the course as a whole and in the way they understood the subject and how it relates to real life. I discuss different aspects of this work and present recommendations for improvement**

Keywords—Experiential Learning, Blended Learning, Lecture Casting;

I. INTRODUCTION

Experiential Learning (EL) is a great tool for teaching engineering concepts [1]. In this approach, students learn through actual experiments the different underlying concepts. It is different from the old class setting where a professor would teach all the concepts and students then apply them to assignments and projects. In EL, students acquire the necessary knowledge on their own with the instructor effectively turned into a supervisor. The bases for EL are many studies that show that knowledge is better learnt and retained through experiences.

Blended Learning (BL) [2] is another learning approach that attempts to better use the precious classroom time. Instead of spending the available classroom times in discussing theoretical concepts, the instructor usually puts his material online in the form of cast lectures for the students in advance. The lecture time is then dedicated for discussions, solving interesting examples, applications, and having quizzes about different aspects of the subject.

Electromagnetics [3] is a subject that would benefit greatly from both approaches. It is feared by most engineering students because of highly mathematical content and its dependence on vector calculus and algebra. Students usually have difficulty envisaging the meaning of the different concepts. They also usually have a problem in linking the abstract equations they study to real-life applications. The nature of the subject and the unclear connection to applications, especially in introductory courses, is what prompted this study.

In this work, we report on an experiment that aims at improving the way electromagnetics are being taught. We utilize a combination of EL and BL in this experiment. The results of the course evaluation which was conducted in an independent way, shows significant improvement in the way the students appreciated the course and the instructor's effectiveness as a teacher.

We start in Section II by describing the experiment and all the tools used to carry it out. We then report on the findings and the feedback used in Section III. Finally, more recommendations for improvements are suggested in Section IV.

II. EXPERIMENT DESCRIPTION

This experiment was conducted in the winter term of 2014 in the introductory electromagnetics course EE2FH3. The class size was 215 students all in one section. The course format included 3 lectures per week and one tutorial. This course did not have any laboratory sessions.

A. The Beginning

Students were informed at the very first lecture that they are a part of an experiment in engineering education. The format of the new course was explained to them. The difference between the way the course was taught in previous years and in the current year was explained.

B. Experiential Learning

Students were informed in this first lecture that they will have to carry out a practical design problem of an electromagnetics structure used by industry. They were given a suggested list of possible electromagnetic structures including microwave filters, photonic filters, impedance transformers, interaction of electromagnetic waves with the human body, microwave antennas, nano antennas, and metamaterials. The instructor gave a brief definition of each class of structures. Students were asked to form themselves into groups of 5-6 members. Each group was then asked to pick up a project and make an initial YouTube presentation about it to the class within one month of the course start. In this YouTube proposal, the students were asked to include an interesting and not-so-technical overview of this class of structures and a detailed explanation of the specific high frequency geometry they plan to design and what are the design specifications. To improve the students' understanding of the different application and to give them a broader overview of applications, the proposal of every group was peer-evaluated by all other groups for clarity, technical content, and quality of proposal.

After the initial proposal was approved by the instructor, students were asked to learn and use the free electromagnetic solver OpenEMS [4] in simulating and designing their structures. Using this solver requires good understanding of the underlying advanced concepts that a practicing engineer would be familiar with. The instructor offered biweekly 15-minutes meeting with every group to check on their progress and give them advices on how to proceed. At the end of their project, students were asked to prepare another YouTube presentation illustrating their structures, the optimal designs they created, and the results they obtained. They were asked also to submit a final written report of this proposal.

C. *Blended Learning*

Students were informed at the beginning of the course that the way the material will be developed in this course will be different. The instructor converted every lecture into a video that was put on YouTube by 5:00 pm the night before the lecture. Students were asked to watch this YouTube lecture and come to the classroom to discuss applications, solve interesting problems, and have quizzes. Effectively, this resulted in having 4 tutorials per week instead of one. The number of solved examples and applications was at least 3 times the number in previous years. The instructor utilized the software DoodleCast Pro available in iTunes in casting his lectures.

Fig. 1 illustrates the general philosophy used in this course. At the lower level of the knowledge pyramid, the instructor taught students the basic concepts during casted lectures and tutorials. At a high level of the pyramid, students are assumed to have already sufficient knowledge to carry out an advanced project that only a practicing engineering would be able to do. They had to acquire the necessary knowledge through reading research papers, online materials, and through the interaction with the instructor.

III. RESULTS

Over 85% of the students were able to successfully finish their projects. Many went beyond what is expected from them. The structures designed by two groups of students are shown in Figs. 2 and 3. In Fig. 2, the propagation of an electromagnetic wave resulting from a cell phone inside a numerical model of the human head was investigated. This project required learning the advanced feature of importing numerical models of biological tissues into the solver. Fig. 3 shows a hairpin-type antenna whose response depends on the geometrical and material properties. The responses obtained from the students work match well those reported in the literature While these

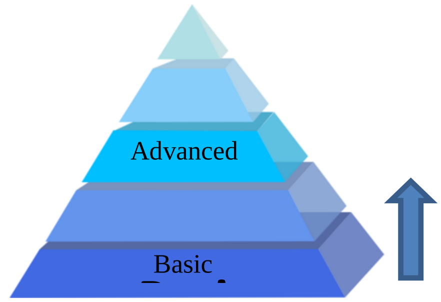

Fig. 1. Course philosophy; at a lower level, students are learning basic theoretical details and at a higher level students are carrying out advanced projects.

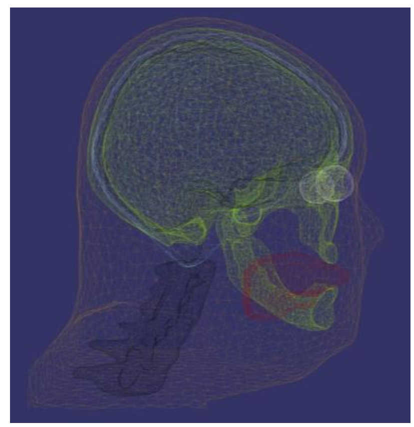

Fig. 2. The numerical model of the human head utilized by the students of one of the groups [5].

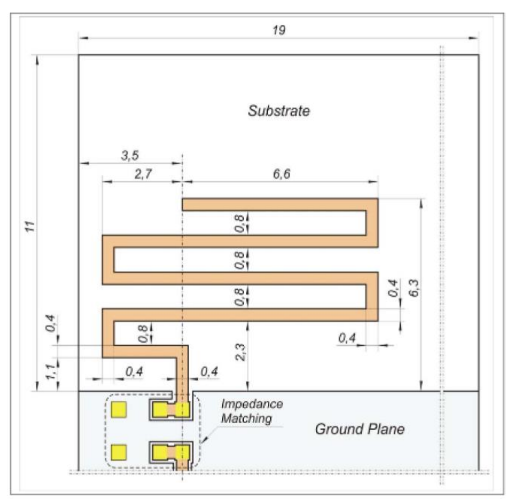

Fig. 3. The Meander antenna simulated by one of the students' groups [6].

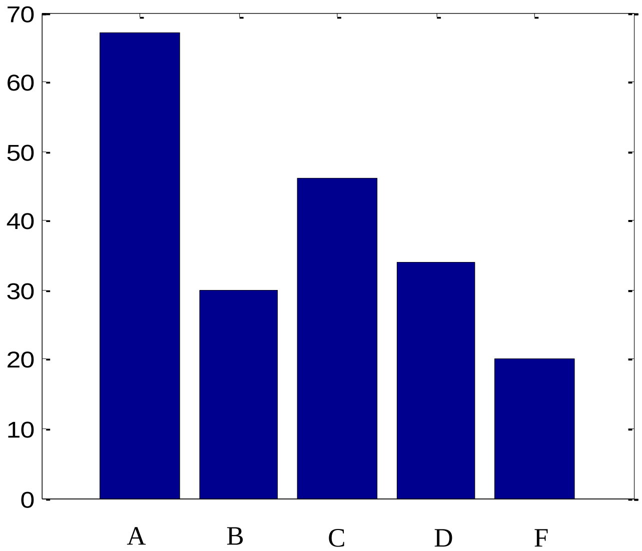

Fig. 4. Course results using Experiential and Blended Learning.

projects are actually graduate-level projects, the second year students were able through experiential learning and regular supervisory interactions to grasp the basic concepts and use them successfully

The final course results showed a bi-modal distribution. Over one third of the students scored in the A- to A+ range. One fourth of the students scored in the C range as shown in Fig. 4. The instructor correlates the result with how the students observed the blended learning methodology. Students who watched the YouTube cast lectures on time and attended the classroom discussions were very likely to do very well in the course. Students who lagged in watching the posted videos and attended the classroom without having the necessary theoretical background ended up doing worse than the other group.

When the instructor taught this course for the first time using traditional teaching methods, he received a below average evaluation as instructor with a score of 6.15 out of 10. Such a score is very common when teaching courses with abstract content such as EE2FH3. In this experiment, and using this combination of Blended Learning and Experiential Learning, the instructor received an above average evaluation of 8.1. Previously, most students would not write any free comments about the course. This time, students wrote over 10 pages of free comments suggesting how to improve this experiment in the future.

IV. Feedback and Suggestions

The vast majority of students' comments were very positive. Except for very few, they all believed that having the lectures posted as videos was very helpful. This gave them the liberty to watch the videos as many times as they want and whenever they want. The main criticism for this approach was the time-constraint. Many students complained that by watching the videos at home and then coming to the classroom, the time for lectures has effectively been doubled. This alone, given the busy schedule they have, have strained them. There were several proposals to eliminate one lecture per week and convert it into office hours to remedy this shortcoming.

Most students liked the idea of having an experiential learning-based project. Most of them felt that the abstractness of the course was significantly diluted by using this project. Some students asked that the online videos be posted way earlier than the lecture time. This was not possible this time as the material was developed as the course proceeded. The experiment was overall very positive and received praise by independent observers.

Acknowledgment

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Aircraft Motion Simulation in Time Domain- A Useful Tool in Flight Mechanics

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Abstract— **The necessary equations and expressions for aircraft motion simulation are introduced in both full non-linear and also linear form. Description of forces and moments acting on the aircraft is also presented since it represents a vital aspect. A suitable technique for numerical integration was given. Implementation of the direct numerical solution to the longitudinal equations of motion was performed. Two cases were investigated, the first one is the effect of the well established stability derivative '$C_{m\alpha}$' and the second one is the effect of gust through five different models, on selected longitudinal motion variables. Results show the clarity of the output. It is in the form of time history, it is readily understood. It requires virtually not much of experience. Suggestions were made to adopt the current approach for education and industrial proposes.**

Keywords—Aircraft motion simulation, Simulation based learning;

I. INTRODUCTION

For aeronautical engineering students and engineers, understanding how the aircraft behaves in air, especially after a disturbance, is a very significant subject. Solving the aircraft characteristic equation for longitudinal and/or lateral motion, is the standard technique used for free response analyses. This technique requires sufficient amount of experience to analyze and investigate. It also does not reflect the status of aircraft behavior in a sufficient clear way.

Another alternative approach is the direct solution in time domain for uncoupled equations (longitudinal and lateral), or even for the full non-linear equations, for the cases where decoupling is impossible. This technique is shown to be a very reliable technique. Direct solution could be performed numerically using the proper numerical integration algorithm and step size. The aircraft response being displayed in time, lends itself to direct interpretation, it requires little or no experience to understand. In this paper, the necessary equations of aircraft motion both in non-linear and decoupled linearized form, along with other complimentary expressions, are presented.

A computer program was prepared, and motion simulation, for a hypothetical aircraft was performed.

II. THE MATHEMATICAL MODEL

Aircraft equations of motion are derived using standard basic laws of dynamics, where details of such derivations could be found in any text of flight mechanics such as in [1]. They are described as first order non-linear ordinary differential equations of constant coefficients. Dealing with the equations in the non-linear form is not a simple task, so the usual way is to simplify them, through some assumptions based on small perturbation theory, to convert them into linear equations. This simplification or linearization process leads to two separate sets of equations, one for longitudinal motion and the other for lateral-directional motion. These two sets of equations could be solved separately. Without going into the details of the derivation, the full non-linear equations of aircraft motion are given as;

$$\dot{u} = \frac{\sum F_x}{m} - qw + rv \tag{1}$$

$$\dot{v} = \frac{\sum F_y}{m} - ru + pw \tag{2}$$

$$\dot{w} = \frac{\sum F_z}{m} - pv + qu \tag{3}$$

$$\dot{p} = \frac{1}{I_x}\left[\sum L - \left(I_x - I_y\right)qr + I_{zx}\left(\dot{r} + pq\right)\right] \tag{4}$$

$$\dot{q} = \frac{1}{I_y}\left[\sum M - \left(I_x - I_z\right)rp + I_{zx}\left(r^2 + p^2\right)\right] \tag{5}$$

$$\dot{r} = \frac{1}{I_z}\left[\sum N - \left(I_y - I_x\right)pq + I_{zx}\left(\dot{p} + qr\right)\right] \tag{6}$$

Equations '1-3' represent the change of linear velocity components (u, v, w) with respect to time, while equations '4-6' represent the rate of change of angular velocity components(p, q, r) about the three body axes (X, Y and Z) respectively. Also 'm' is the aircraft mass, and I_x, I_y, I_z, and I_{xz} are the standard moments and product of inertia. In addition to these six equations we may add three equations representing the change of the three Euler angles (the pitch angle θ, the roll angle ϕ, and the yaw angle ψ) which give the orientation of the aircraft as;

$$\dot{\theta} = q\cos\phi - r\sin\phi \tag{7}$$

$$\dot{\phi} = p + q\sin\phi\tan\theta + r\cos\phi\tan\theta \qquad (8)$$

$$\dot{\psi} = (q\sin\phi + r\cos\phi)\sec\theta \qquad (9)$$

In the upper equations, $\sum F_x$, $\sum F_y$, and $\sum F_z$ are the externally applied forces on the aircraft, while $\sum L$, $\sum M$ and $\sum N$ represent the three applied moments. The upper equations could be put in the linearized form after introducing some simplifying assumptions; they are separated into two independent sets, one for longitudinal motion and the other for lateral-directional motion. Fore ample the longitudinal equations are given as;

$$\dot{u} = \frac{\sum F_x}{m} - qw,\ \dot{w} = \frac{\sum F_z}{m} + qu,\ \dot{q} = \frac{1}{I_y}[\sum M],\ \text{and } \dot{\theta} = q \qquad (10)$$

III. Description of Forces and Moments

With aircraft motion modeling, estimation of the aerodynamic forces and moments is the most significant and also difficult part of the process. Experience and physical insight has led to determination of the most affecting motion variables. These forces and moments are expressed in terms of the relevant stability and control derivatives [1]. The description of such forces and moments is given as;

$$\sum F_x = T - mg\sin\theta + (C_x + C_{x\delta e}.\delta_e)\bar{q}S \qquad (11)$$

$$\sum F_y = mg\cos\theta\sin\phi + (C_{y\beta}.\beta + C_{y\delta a}.\delta_a + C_{y\delta r}.\delta r)\bar{q}S \qquad (12)$$

$$\sum F_z = mg\cos\theta\cos\phi + \begin{bmatrix} (C_{ZT} + C_{Z\alpha}(\alpha - \alpha_T) + C_{Zq}(q\bar{C}/2V) \\ + C_{z\dot{\alpha}}(\dot{\alpha}\bar{C}/2V) + C_{Z\delta e}\delta_e \end{bmatrix}\bar{q}S \qquad (13)$$

$$\sum L = \begin{bmatrix} C_{lT} + C_{l\alpha}(\alpha - \alpha_T) + C_{l\beta}.\beta + C_{lp}.\left(\frac{pb}{2V}\right) \\ + C_{lq}\left(\frac{q\bar{c}}{2V}\right) + C_{l\dot{\alpha}}\left(\frac{\dot{\alpha}\bar{c}}{2V}\right) + C_{lr}\left(\frac{rb}{2V}\right) \\ + C_{l\dot{\beta}}\left(\frac{\dot{\beta}b}{2V}\right) + C_{l\delta_a}.\delta_a + C_{l\delta r}.\delta r \end{bmatrix}\bar{q}Sb \qquad (14)$$

$$\sum M = \begin{bmatrix} C_{mT} + C_{\alpha}(\alpha - \alpha_T) + C_{m\beta}.\beta + C_{mp}.\left(\frac{pb}{2V}\right) \\ + C_{mq}\left(\frac{q\bar{c}}{2V}\right) + C_{m\dot{\alpha}}\left(\frac{\dot{\alpha}\bar{c}}{2V}\right) + C_{mr}\left(\frac{rb}{2V}\right) \\ + C_{m\dot{\beta}}\left(\frac{\dot{\beta}b}{2V}\right) + C_{m\delta_e}.\delta_e \end{bmatrix}\bar{q}S\bar{c} \qquad (15)$$

$$\sum N = \begin{bmatrix} C_{nT} + C_{n\alpha}(\alpha - \alpha_T) + C_{n\beta}.\beta + C_{np}.\left(\frac{pb}{2V}\right) \\ + C_{nq}\left(\frac{q\bar{c}}{2V}\right) + C_{n\dot{\alpha}}\left(\frac{\dot{\alpha}\bar{c}}{2V}\right) + C_{nr}\left(\frac{rb}{2V}\right) \\ + C_{n\dot{\beta}}\left(\frac{\dot{\beta}b}{2V}\right) + C_{n\delta_a}.\delta_a + C_{n\delta r}.\delta r \end{bmatrix}\bar{q}Sb \qquad (16)$$

In the above summations F_X, F_y, F_z are the externally applied forces, while L,M,N are the resulting moments about the body axes which are centered at the aircraft C.G. 'T' is the thrust force, 'S' is the reference area, '$\bar{q}$' is the dynamic pressure, '$\bar{c}$' is the mean aerodynamic chord, $C_{z\alpha}$, C_{zq} etc are the standard stability derivatives, δ_e, δ_a, and δ_r are the elevator, aileron and rudder deflections respectively . The subscript (T) refers to trim condition. To complete the analysis, equations for the rate of change of aircraft position (X Y, Z) with respect to a fixed point on earth, also the equations for the angles of attack, sideslip and their rates of change are required;

$$\dot{X} = u\cos\psi\cos\theta + v(\cos\psi\sin\theta\sin\phi - \sin\psi\cos\phi) + w(\cos\psi\sin\theta\cos\phi + \sin\psi\sin\phi) \qquad (17)$$

$$\dot{Y} = u\sin\psi\cos\theta + v(\sin\psi\sin\theta\sin\phi + \cos\psi\cos\phi) + w(\sin\psi\sin\theta\cos\phi - \cos\psi\sin\phi) \qquad (18)$$

$$\dot{Z} = -u\sin\theta + v\cos\theta\sin\phi + w\cos\theta\cos\phi \qquad (19)$$

$$\alpha = \tan^{-1}(w/u), \dot{\alpha} = (u\dot{w} - \dot{u}w)/(u^2 + w^2), \quad \beta = \tan^{-1}(v/u), \dot{\beta} = (u\dot{v} - \dot{u}v)/(u^2 + v^2) \qquad (20)$$

$$V = (u^2 + v^2 + w^2)^{1/2} \qquad (21)$$

IV. Numerical Model

The above equations either in the full non-linear form or in the linearized form could be numerically integrated using the proper scheme and integration step, and the proper initial condition before perturbation (e.g trim conditions for straight and level flight). The fourth order Runge-Kutta process has been used successfully for this purpose. The error with this process is in order of $(\Delta T)^5$, where ΔT is the integration step size, with time is the independent variable. Details of this technique could be found in many texts dealing with numerical methods and applications [2, 3]. The numerical stability of solutions depends upon the choice of the suitable integration step size, and the accuracy is quite acceptable according to engineering practical standards, since the error in the process is the step size raised to the power five. We should always keep in mind that numerical solutions are approximate solutions, however they are very handy from practical engineering point of view.

V. Results of Numerical Simulations

As we mentioned earlier, the equations of motion could be integrated numerically along with other related expression to give full picture of the aircraft behavior. Both versions; the full non-linear equations [4] and the linear equations have been used for this purpose. In this paper some sample results using computer simulation and solving the aircraft equations of motion numerically are presented for aircraft decoupled equations. The longitudinal equations are used to investigate the aircraft response to different models of gust, and to investigate the significance of the well established stability derivative '$C_{m\alpha}$' . A lot of material could be found in both subjects in many text books dealing with aircraft stability [1, 5, 6].

Figs. 1 to 3 below show the time history of some longitudinal variables namely the angle of attack (α) and the pitch velocity (q) after impulse elevator perturbation with different values of the stability derivative '$C_{m\alpha}$'. This is in fact a well known stability derivative. It reflects the degree of static stability of the aircraft. In other words it is known to be the deciding factor with regard to static stability, the more negative the value of $C_{m\alpha}$ the more statically stable the aircraft is. Static stability is a requirement of dynamic stability. Therefore the effect of this stability derivative is quite obvious as we look upon the motion time history. Comparing Fig.1 with Fig. 2 gives a direct impression that with $C_{m\alpha}$ positive i.e. statically unstable configuration, the aircraft is dynamically unstable, the figure talks by it self, were 'α' went into unreasonable values. This infract represents a very unstable case.

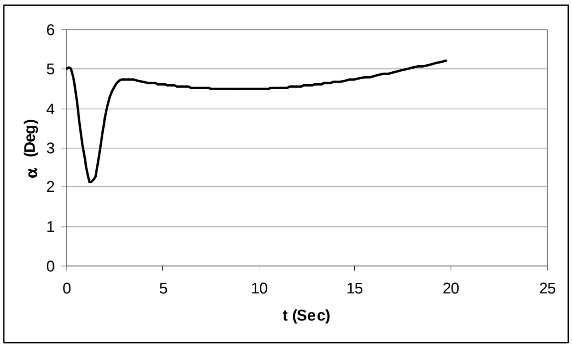

Fig. 1. Effect of $C_{m\alpha}$ ($C_{m\alpha}$=-0.3), after elevator impulse perturbation.

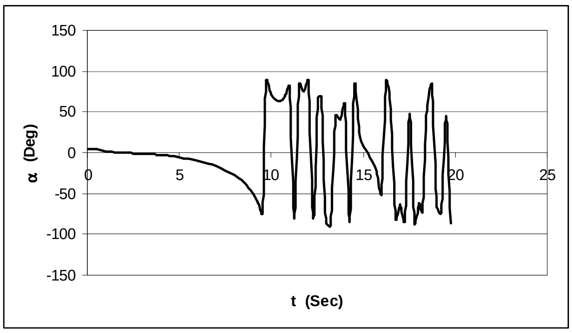

Fig. 2. Effect of $C_{m\alpha}$ ($C_{m\alpha}$=+0.3), after elevator impulse perturbation.

Fig. 3 below shows the effect of the respected stability derivative being small negative value (-0.05) i.e. just stable configuration, and a small positive value (+0.05) i. e. just unstable configuration. Changes in the angle of attack indicate little dynamic stability for the negative value case compared with the stability derivative being given the nominal value Fig. 1. In this case it will take the angle of attack a very long time to come back to the steady state value. The same trend with positive value derivative i.e. the behavior is still unstable but with less degree of instability compared to Fig. 2.

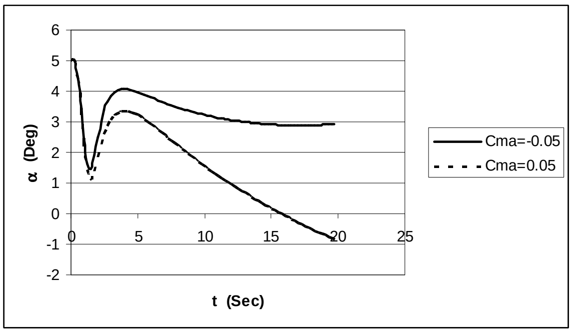

Fig. 3. Effect of $C_{m\alpha}$ ($C_{m\alpha}$=±0.05), after elevator impulse perturbation.

An investigation into the effect of different models of longitudinal gust, on the longitudinal motion, was done using the linearized longitudinal equations of motion. A trim angle of attack of "5 deg.' was the initial condition before the beginning of perturbation in the form of gust. In this investigation five models of gust (G1-5) were used;

(G1)- Sharp gust, (G2)-sinusoidal gust, G3-ramp gust, G4-trapezoidal gust, and G5-(1-cos) gust. The free response of the hypothetical aircraft is given in Figs. 4 and 5 below. Changes of the angle of attack and the pitch angular velocity up to 40 seconds of simulation are presented. They are quit evident changes with every gust model. The gust model (1-cos) gave the minimum effect among the five models investigated. In these simulations the components of wind velocity where taken as u_g=5 m/sec, and w_g=2 m/sec. the effect of gust was introduced after one second from the begging of simulation. Investigation of gust effect on aircraft motion is a vital subject regarding safety operations of aircraft and comfort of passengers. In such investigations many other information could be found such as the vertical component of the acceleration where this is an important information from ride comfort point of view, however they are not presented here because of limited space and time.

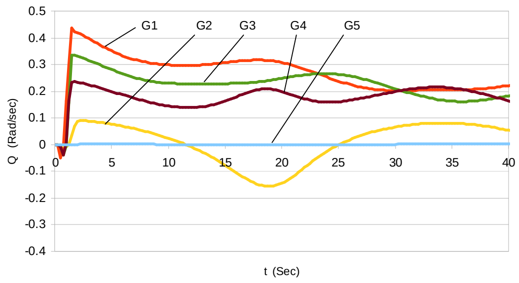

Fig. 4. Aircraft pith velocity response to different models of gust.

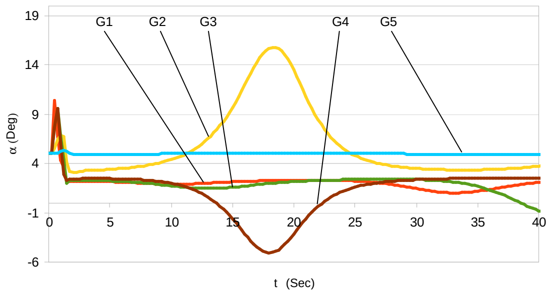

Fig. 5. Aircraft angle of attack response to different models of gust.

VI. Final Concluding Remarks:

Direct solution of aircraft equations of motion may represent a useful tool in flight mechanics. Using the proper equations and the suitable numerical integration scheme gives results that can be easily understood and interpreted. This technique lends it self to treat very difficult cases where decoupling of equations and building the characteristic equation is impossible. The numerical integration with 4th order Runge-Kutta process requires only the value of the variable and it is derivative at the starting time. The error is within the engineering accuracy. Therefore; besides the traditional way of solving the characteristic equation we suggest that the approach discussed in this paper be introduced as well since it represents a very handy tool for education and industry applications.

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Integrating Lectures, Laboratories and Course Projects

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Abstract*—In the teaching of engineering programs, laboratories are sometimes offered in conjunction with large lecture courses so that students may acquire technical skills and apply concepts and theories presented in lecture. However, in many cases laboratories are offered as “stand-alone” courses with no connection to any other parent course. In fact, even where laboratories are related to a parent course, they often have their own agenda that in many cases is not related to lectures. This teaching approach is contrary to what is generally agreed in literature, that comprehension improves when people learn concepts through multiple methods. In this paper we present a learning paradigm that ensures that the core concepts of courses are presented to student through lectures, laboratories and course projects. This approach ensures that students learn the key concepts of courses through multiple methods. When we used this approach to teach the course Industrial Controllers and Networks in the Bachelor of Technology program at McMaster University, results showed that students’ comprehension in the associated course material improved. Moreover, we received a lot of positive feedback from the students. In the future, we would like to carry out a former study to determine the educational effectiveness of this learning paradigm.

***Keywords*—Engineering-programs, Lectures, Laboratories, Course-Projects, Learning-Paradigm**

I. Introduction

In general, students prefer different learning styles. This usually causes difficulties for instructors to gain attention of students and ensure that they learn effectively. For some students a demonstration or a model they can see and touch is what stimulates their comprehension. For others, it is a video of an application of the concept that makes it click. Some want to work one-on-one with the instructor, while other students find it easy to learn through small group discussions. This is in no way an exhaustive list, and it is the responsibility of the instructor to identify and utilize the various teaching modes that are appropriate for their courses [2]. It should also be noted that, it is generally agreed in literature that individual students learn better if the material is presented to them through multiple modes [1, 2]. Therefore, it is important that course instructor use multiple teaching modes to ensure effective learning for all students in the class.

The first part of this paper presents how we used multiple teaching modes in the course, Industrial Controllers and Networks, in the Bachelor of Technology program at McMaster University. In the second part of the paper we describe an example topic that was covered in a class lecture, and how the lecture material was thereafter used in laboratory work. Moreover, this part of the paper describes how both the lecture material and laboratory work was related to and used in the course project.

The rest of this paper is arranged as follows: In Section II we present the background of our teaching approach and in Section III we present a description of an example topic that we taught using multiple modes. Finally, we present the conclusion and future work in Section IV.

II. Background

Most learning material of the Industrial Controllers and Networks (ICN) course in the Bachelor of Technology program at McMaster University is first presented to students through lectures. These lectures include some small group discussions and class quizzes or take home assignments. Thereafter, students do laboratory work in which lecture material is applied. In some topics, the material covered in lectures and in laboratories is directly applied in the course project.

A. Lectures

During the lecture mode of the course material delivery in the ICN course, some questions are posed to students to stimulate discussions. These questions are designed to create a backward and forward review of the course material. Moreover, the questions are design to enable students to relate concepts learned from different topics, and to develop generalizations from the course material. For example in one lecture the following questions were posed to the students:

- *What is meant by the phrase “intrinsically safe network?”*
- *Beside Profibus PA, what other network protocols have we covered that are intrinsically safe?*
- *If a network is not intrinsically safe, can it be used in an explosive environment? Why or why not?*

The students were asked to work together in triads to come up with answers. Afterwards the student groups switched papers in order to grade the questions as the instructor explained the answers. This activity provided an opportunity for peer-learning and encouraged the students to learn the key concepts in more depth through active learning. It also provided immediate feedback to students on their level of understanding of the course material. Moreover, the activity helped students to reflect on the already covered course material and how it related to the general use of communication networks.

B. Laboratory Work

Laboratory work in the ICN course is closely associated with the lecture material. This work in categorized into three groups, namely:

- *Microcontroller labs:* These labs cover the selection and programming of microcontrollers. They are associated with the microprocessors and controllers topics covered in the lectures.
- *Networks labs:* The network labs cover socket programming, Ethernet to RS232 conversion, Ethernet TCP/IP and Radio Frequency communication. These labs are associated with lecture material covered in topics such as communication, networking fundamentals, as well as industrial networks and TCP/IP.
- *Introduction to system integration labs:* These labs cover controller-sensor/actuator interfacing, introduction to motion control and introduction to vision systems. They are associated with lecture material in the microprocessor and controllers topics.

C. Course Project

The course project focuses on microcontroller programming as well as interfacing of microcontroller with sensors and actuators. It is also used to strengthen students' knowledge in circuit analysis and design, a topic that is covered earlier in another course. The Networks component of the ICN course is not included in this project. This is because the component is covered in a project of another course for which the ICN course is a prerequisite. That project is the focus of our paper titled, "Laboratory Based Project for Experiential Learning in PLC Systems Integration and PLC Systems Data Access", which appears in the proceedings of the Canadian Engineering Education conference, Canmore – Alberta, June 2014 [5].

III. EXAMPLE OF INTEGRATED TEACHING

In this section we describe how we used multiple modes to teach the microcontroller programming and microcontroller-sensor/actuator interfacing topic in the ICN course.

A. Lecture Component of the Example Topic

In the lecture component of the example topic of microcontroller programming and microcontroller-sensor/actuator interfacing, we covered the following subtopics: microcontroller selection, memory estimation, analog to digital conversion, analog value to physical parameter conversion, controller-sensor interface and controller-actuator interface. Figure 1 shows a summary of the material covered in the example topic. Moreover, the figure shows that some actuators and sensors need interfaces to be connected to the controllers. These interfaces work as characteristics matching devices for the controllers and sensors/actuators.

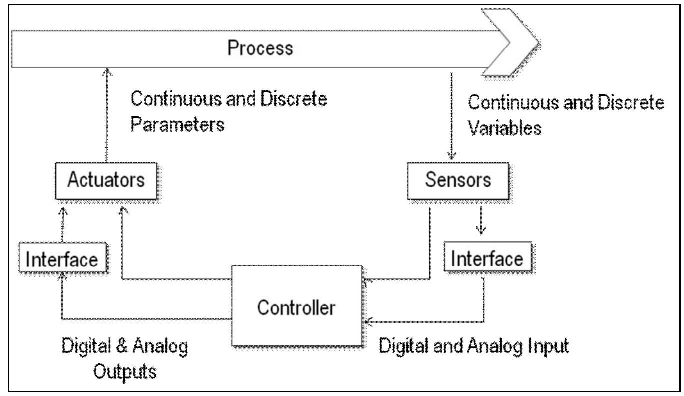

Fig. 1. Summary of the example course topic

To spur discussions among students during the lecture component of the topic, students were given questions such as:

- *Explain how a 2mV/V rated load sensor would be interfaced with a controller whose analog input voltage rang is 0-5V.*
- *Explain how a Light Dependant Resistor (LDR)/Light Emitting Diode (LED) combination is used to sense colors, and how the combination can be connected to a microcontroller that operates on a 5 Volt power supply.*
- *If developing a system that involves measuring temperature 0-100 deg. and accuracy of 0.2 deg. What is the minimum number of bits a microprocessor for this application have?*

Moreover the students were given the following take home assignment:

Design a DC motor drive for 12V DC motor, using the L293D IC. You should be able to control the stop, forward and reverse motion of the motor. Assume that the motor is to be controlled by a microcontroller, whose output is limited to 3-5V DC.

The students were instructed to hand in hard copies of the assignment solution during one of the lab sessions.

B. Laboratory Component of the Example Topic

In this laboratory, students were required to send a Radio Frequency (RF) signal from the transmitting circuit shown in Figure 2 to the receiving circuit shown in Figure 3. The transmitting and receiving circuits use TWS-434 transmitter and RWS receiver and R-8P series 4-bit encoder/decoder from Reynolds Electronics [3].

On power-up the R-8P series 4-bit encoder enters low power sleep mode. When a data input pin is pulled high, the encoder will wake up and begin the transmit process. First, the encoder will record the state of the data lines, encode for error correction and assemble the packet. It will then sample the BAUD select pin to set the data rate, and then output the encoded data packet on DOUT. The encode and transmit process will continue for as long as any data input pin is high, and return to low power sleep mode when all data input pins return low. It will update the state of the data lines before sending each packet, and finish the current transmission even if all data inputs are returned to ground. On the other hand, on powering up the R-8P series 4-bit decoder enters a timed loop waiting for the synchronization byte. An internal 16-bit timer is used to force an exit from the receive loop, and reset the output pins every 65.5mS if no valid synch byte is received during this time period. Note that 65.5mS is the maximum time the decoder will hold an output high unless a continuous valid data stream is being received. Once a valid synch byte is received, the timer is disabled, and the remainder of the data packet is received and stored for the verification process. Immediately after receiving a valid data packet the decoder begins the process of verifying the data, and checking for errors. Once data has been verified, the decoded data will be placed on the output pins, and the decoder re-enters the timed loop waiting for the next valid packet. Holding encoder data inputs at logic 1 will cause decoder outputs to remain at logic 1. Any break or interruption during the data verification process will cause the decoder to reset all outputs to ground [4]. Consequently, when the micro switches in Figure 2 (one at a time), were pressed, the LED and the buzzer in Figure 3 were activated. The students were then asked to discuss their observations.

In the last part of the laboratory, students were asked to submit the assignment that had been given to them in class. This assignment was marked and reviewed in the lab, and a correct solution was shared among all students (see Section III. A). Figure 4 shows a complete solution of the assignment that was given to students. In the figure, V_{CC1} is the driver supply voltage, V_{CC2} is the supply voltage for the motors M. Pins 1 and 9 are the Enable pins, while pins 2, 7, 10, and 15 are control pins. Each student group decided on the voltage levels of V_{CC1} and V_{CC2} and on how to connect the motors.

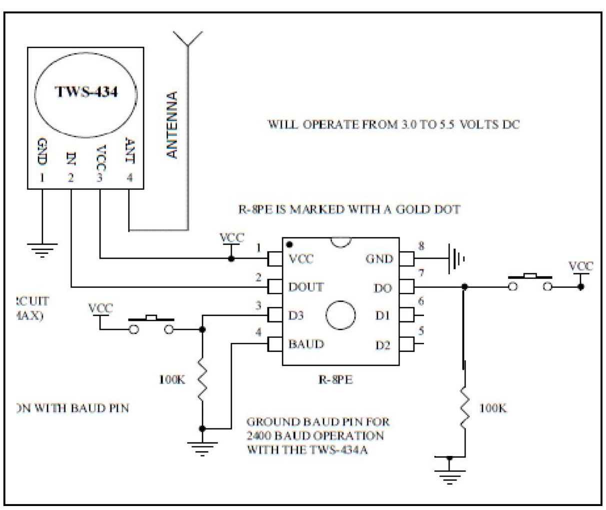

Fig. 2. RF Transmitter

This solution was adopted from Texas Instruments' quadruple half-H drivers manual [6]. Thereafter, students were given the following instructions:

1. Build your motor control circuit from assignment 2
2. Apply 5V to the control PIN of your circuit, and note your observation.
3. Remove the LED and the resistor connected to PIN 3 of the R-8PD IC in Figure 3
4. Connect the control of your circuit in part 1 to PIN 3 of the R-8PD IC in Figure 3

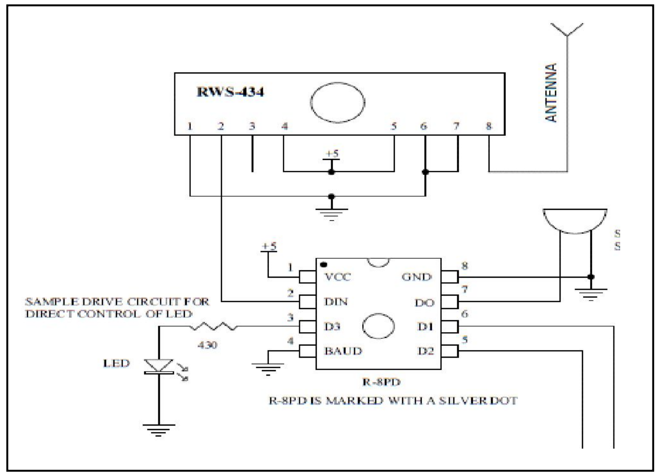

Fig. 3. RF Receiver

5. Press the micro switches in Figure 2 (one at a time), while examining the behaviour of the circuit in Figure 3.
6. Modify the circuit in Figure 3, so that you can control the forward and reverse motion of the motor.
7. Discuss your results

In addition, students examined the effect of removing the freewheeling diodes.

A. Project Component of the Example Topic

In this course project, students were given the following problem:

In this project students working in groups of 2 to 3 shall be required to design, build and test a small robot that will use autonomous control to follow a black line ¾ inches wide drawn on white background course. It shall be required that the robot follows the line in a short period of time while accurately tracking it from start to finish. To assess the performance of the robot each group will present their robot on the line course prepared for the test drive. The line course will have a number of corners, and it will be approximately 2 metres long. Moreover, the students shall produce a project report.

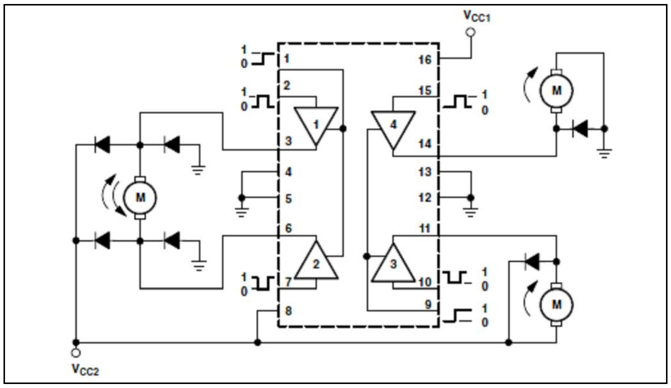

Fig. 4. Assignment solution (Adopted from Texas Instruments' quadruple half-H drivers manual [6])

Notes:

1. *The robot shall be based on the MSP430 microcontroller. No other microcontroller shall be allowed.*
2. *All components for the project shall be provided*
3. *Students shall be allowed to substitute some of the components to up to $10 total. Note that those who decide to substitute some of the component; shall bear the cost of doing so. Moreover, the microcontroller cannot be substituted.*
4. *Those who choose to substitute some of the components; shall have to show a design based on the provided components; and an explanation why they had to substitute those components.*
5. *None technical reasons for substituting component may lead to loss of marks*
6. *All component substitutions shall need to be approved by the instructor.*
7. *Destruction of any of the components may lead to loss of marks. Students shall replace the destroyed components at their cost.*

To carry out this project students had to utilize knowledge acquired from other course such as Electricity and Electronics, and from other course topics and laboratories such as microcontroller programming. Figure 5 presents an example of the circuits that were produced by students. In this circuit, a 9V battery was used to power the robot car. Two regulators were incorporated to provide 5V to power the L293D motor drive as well as its enable pins and 3.3V to power the MSP microcontroller. The motors were powered directly by the battery. The LDRs are connected to the two analog input pins (P1.6 and P1.7) of the microcontroller, and the direction of the motors is controlled through 4 digital output pins.

IV. CONCLUSION

The description in Section III shows that students were taught the topic on microcontroller programming and microcontroller-sensor/actuator interfacing through multiple modes. The students learned through lecturing and small group discussions.

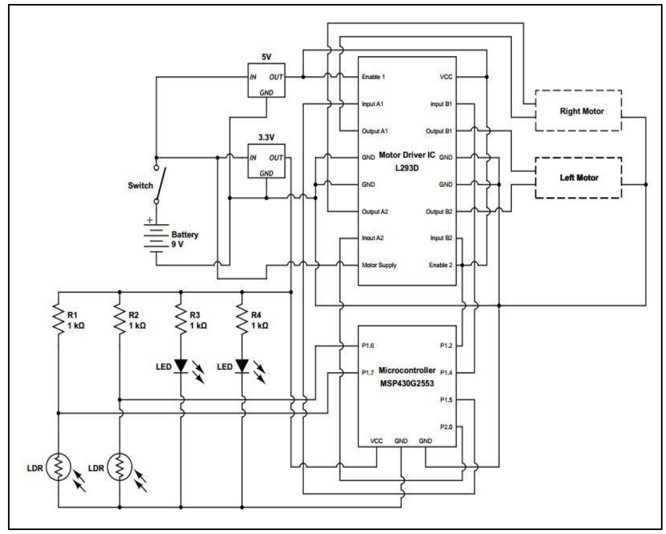

Figure 5: Example Circuit of car robot

They also took home an assignment that was later used in a laboratory. Thereafter, the student applied and extended their knowledge in the topic through a project. In this case, those students who learn better from lectures were accommodated. We also accommodated those who learn better through discussions, or hands-on activities. Moreover, every individual student had the opportunity of having the topic material presented them through multiple modes. A review of students' marks showed that they performed better in those topics which we were able to present to them through multiple modes. Students also performed very well in the robot project, with a class average mark of 85.6%.Furthermore, we received a lot of good feedback from the students about the way this topic was taught. In the future we would like to carry out a formal study to determine the correlation between students' performance and teaching through multiple modes.

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Global Competence, Innovation and Creativity in STEM Education

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***Abstract*–It is known world wide that STEM (Science, Technology, Engineering and Mathematics) Education is critical in an effort to prepare our students and promote innovation, creativity, global competence, democratic principles and social justice, improve economic competitiveness, and provide leadership. Offering our students an in-depth knowledge and understanding of international issues can enhance their global competence, and helping them acquire skills to function productively with people from diverse cultural background makes them successful in career and life. This can be done improving their ability to compete globally. To compete "students need high-level thinking skills that enhanced creativity and innovation." Students who gain thorough understanding of concepts, technology and tools, and computational skills in science, mathematics and engineering that involves real life problems with global issues strengthen their ability to compete in worldwide marketplace. The goal of this project is to present with a research, design, create and develop academic content in a course related to global focus in accordance with students' level of mathematical understanding, and then implement and assess the outcomes. Students acquire the concepts of mathematics and technology that they need to learn, with a focus on global issues and international perspectives on collaboration and innovation. Students get engaged on problems related to selected topics from STEM fields. By the end of the semester, the students possess more diverse and knowledgeable view of the world, comprehend global dimensions, solve problems that arise in everyday life in different societies and the workplace, and hold global competencies throughout their life**.

Keywords–Sustainability, Innovation and Creativity, Engaged Learning, Technology

I. INTRODUCTION

According to National Education Association (NEA) 2010 policy brief, "There is widespread recognition that a thorough understanding of global issues is critical to the United States' efforts to promote democratic principles and social justice, improve our economic competitiveness, and provide leadership in innovation and creativity." Offering our students an in-depth knowledge and understanding of international issues enhances their global competence, and helping them acquiring skills to function productively with people from diverse cultural background makes them successful in career and life. This can be done improving their ability to compete globally. To compete "students need high-level thinking skills that enhanced creativity and innovation." Students who gain thorough understanding of concepts, technology and tools, and computational skills in mathematics that involves real life problems with global issues strengthen their ability to compete in worldwide marketplace. This paper addresses relevant issues to enhance global competence, innovations and creativity. Several perspectives regarding mathematics modeling and the practical applications are discussed in [3]. Students need to be equipped with the ability to apply mathematics to solve practical problems, and create relations between mathematics and reality. The focused goals are to enable our students to understand central aspects of our universe, and foster and enhance motivation and attitude towards mathematics [1].

II. GLOBAL COMPETENCE, MATHEMATICAL TOPICS AND TECHNOLOGY

Global competence is defined as the acquisition of in-depth knowledge of international issues, ability to work with people of different cultural background and the skills to achieve productivity in the world community [2]. Some of the topics on global issues can be effectively implemented in first semester mathematics courses like pre-calculus. The main mathematical topics of this course is to learn about Functions, their names and appearances: algebraically and graphically and their applications. The other topics that are covered are Analytic Trigonometry, Analytic Geometry, System of Equations, and Sequences and Series.

Increasing availability of new technologies changed how teaching and learning of mathematics occurs in the classroom around the world. The course uses various forms of technology and explores the impact of technology on students' learning and behavior. Particularly its ability to expand students' access to information, reduce the cognitive requirements of classroom tasks, and enable students to demonstrate understanding using various media is incorporated. In particular, students use scientific and graphing calculators, networked electronic notebooks, and laptop computers equipped with computer algebra systems, and Internet access as needed. Students make presentations using power point and prepare undergraduate research documents.

A. Basic Skills under General Education

This course can be used to satisfy the university requirements for basic skills in mathematics under general education program. It includes requirements and learning activities that promote students' abilities as described below.

Use logical reasoning by studying mathematical patterns and relationships by functional notations and the combination of functions, such as sums, products and compositions. Know mathematical formulas involving variation. Understand the relation between exponential and logarithmic functions and the simplification of expressions using the trigonometric identities.

Use mathematical models to describe real-world phenomena and to solve real-world problems. Comprehend the limitations of models in making predictions and drawing conclusions. Differentiate linear models for bivariate functions, exponential models for growth or decay, and periodic models with trigonometric functions. Examine the properties of trigonometric quantities by the use of the unit circle.

Organize data, communicate the essential features of the data, and interpret the data in a meaningful way. Find the domain and range of a function. Use functional notation to show the relation between variables. Calculate the average rate of change is from a graph, a function or a table.

Express in words, clearly and correctly, the relationships illustrated in graphical displays and tables with a number line graph by using interval notation and inequalities. Identify and express the characteristics of the graphs of powers, polynomials, rational functions, exponential, and trigonometric functions. Recognize increasing and decreasing intervals, curvature, local optima, and long-term behavior of a given function from its formula, or a graph. Explain how transformations change the characteristics of a function and graph the transformed function.

B. International Issues

Here are some of the selected projects related to international issues, Climate Change and Global Warming, Biodiversity, Energy Consumption, Wasted Labor, International Currencies, Sustainability Development, and Space Math that can be implemented.

The growth trend and development of Carbon Dioxide (CO_2) emissions in US over a span of 30 years is given in [4]. The emission of carbon dioxide in US affects the entire world. US is considered as global giant economically and in innovations but its emission of carbon dioxide is highly criticized worldwide. Clouds of carbon dioxide make it harder for solar radiation to leave Earth's surface causing it to retain all the heat. When the earth's surface heat up it brings all kinds of catastrophic changes to the global climate. Students learn to collect data, plot them to find a best fit function and analyze its nature. With these activities they are able to understand different aspects of the function related to this issue. Although US accounts for 4% of world's population, it accounts for 20% of carbon dioxide emissions and 40% of industrialized country emissions as shown in Fig. 1. Understanding the locations of different countries in the world map, the students are able to predict climate change for different countries.

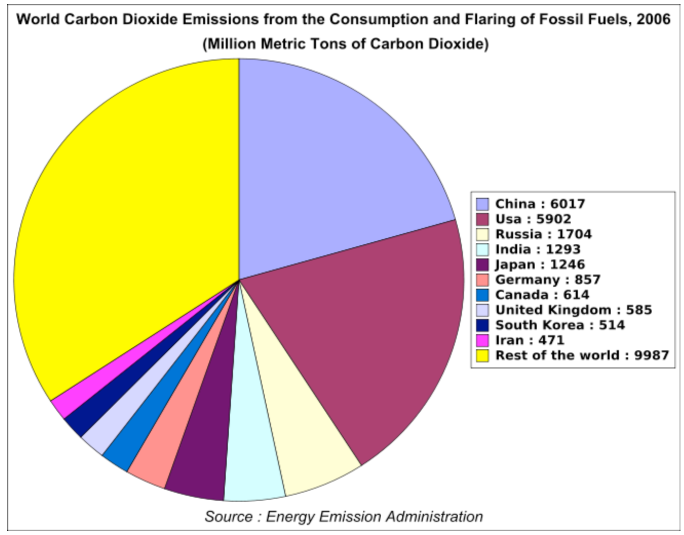

Fig. 1. Carbon Dioxide emissions

The existence of Biodiversity, the number of species plants, animals and organisms, the enormous diversity of genes in these species plays an important role for the health of this world [5]. The different ecosystems on the planet maintain biological diversity of this earth. Even though humans dominate the earth, it is important to understand that the larger number of plant species means more variety of crops, greater variety of animal species ensures sustainability of life, and healthy ecosystem means easier to withstand and recovery from natural disasters. Students will work with graphs and functions (including exponential and logarithm functions) and understand the importance of maintenance of biodiversity.

Equity in the consumption, consumerism and distribution of available energy is an important global issue for the students to understand [6]. It has been stated that the poorest 10% only accounts for 0.5% and the wealthiest 10% accounts for 59% of all consumption. Students need to learn the patterns and effects of consumption. Inequalities in consumption are making a striking difference. Globally, 20% of the world's population in the higher-income countries accounts for 86% of total private consumptions and the 20% of world's population in the lower-income countries accounts for 1.3% of total private consumption. Students will have to understand global priorities (basic education for all, water and sanitation over the globe, reproductive health for all women, and basic needs for health and nutrition for all) and what they can do or should not do to protect the environment.

The mathematics of wasted labor and food are a nerve-racking topic that students are completely unaware of [7]. On the average only 4.4 hours of a typical employee's workday are used productively. About 1.2 hours are lost due to personal and other unavoidable delays, while 2.4 hours are simply wasted. Nearly 35% of wasted times is due to poor scheduling of workers, 25% is due to unclear communications of assignments, and 15% is due to improper staffing. More wasting is reported due to absenteeism and tardiness.

Statistics says that up to a third of world's food is wasted as shown in Fig. 2. This is equivalent to 400 to 500 calories per person per day in the developing world and as much as1500 calories per person per day in the developed world.

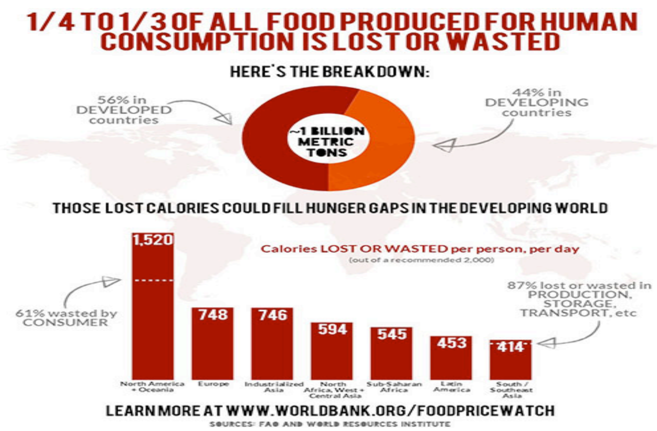

Fig. 2. Food waste

Efficiencies of technology can add to the productivity and minimize food and labor waste. Students research and make global comparison between countries on wasted labor with mathematical calculations.

Issues related to International Currencies and how it impacts the US dollar are important concepts for our students to understand [8]. Currently, students have limited idea how US currency play a major role in a global market. Production costs of dollar bills are much lower than its actual value. US citizens can consume more and save less in comparison to the other countries. It allows US to import more goods and capitals than it exports. However, the significant weakening of the US economy weakened the global stock markets. Students will plot the value of a commodity with respect to different currencies to understand what this means. For example an airline ticket in Austrian currency costs \$550 (when converted) and bought at Austrian airlines website while the same ticket in US costs \$720 when bought at Orbitz.

Recently, the United Nations Educational, Scientific and Cultural Organization's (UNESCO) Decade of Education for Sustainable Development (DESD) [9] stated, "Sustainable development, a constantly evolving concept, is thus the will to improve everyone's quality of life, including that of future generations, by reconciling economic growth, social development and environmental protection". Students will use data sets, worksheets, graphs, mathematical background and content to understand sustainability issues and concerns. Students will use real world information for questions and problems in Mathematics.

SpaceMath@NASA [10] offers and introduces students to the use of mathematics in today's scientific discoveries. Students gain more understanding of our world and its position and various activities in the space while doing problems related to our space. For example, students calculate approximate dates of two solar eclipses in a year and from where on earth that can be visible based on geometry and mathematics of proportionality. Students use the knowledge of conic sections, in particular, equation of a parabola and find focus for a solar cooker and a sound amplifier dish as shown in Fig. 3.

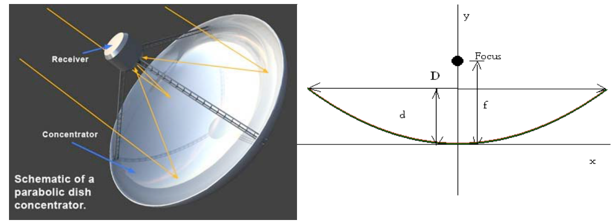

Fig. 3. Satellite dish with a radio receiver

III. STUDENT LEARNING OUTCOMES

Based on the departmental common assessment and the university policy [11] the following items are used to fine-tune the course curriculum and coordinate the pedagogical resources to accomplish the appropriate level of student learning outcomes.
Expectations: What to expect our students to know and be able to do as new professionals.
Preparation: How curriculum and teaching methods help students to meet these expectations.
Assessment: How to know if the students are progressing appropriately towards meeting these expectations.

All the student learning outcomes, listed below, are attained via international issues and concerns related to the projects, Climate Change and Global Warming, Biodiversity, Energy Consumption, Wasted Labor, International Currencies, Sustainability Development, and SpaceMath. For example, the project on growth trend and development of Carbon Dioxide (CO_2) makes students to understand different aspects of mathematical pattern and make predictions based on logical reasoning; the study on Biodiversity makes students to conceive how exponential and logarithm functions work in nature, and understand the importance of maintenance of biodiversity; with the SpaceMath@NASA information students confirm their understanding of trigonometric functions while calculating approximate dates of two solar eclipses in a year and from where on earth that can be visible, based on geometry and mathematics of proportionality; and so on.

Students use *logical reasoning* by studying mathematical patterns and relationships that includes functional notation and identifiers. Students learn the *combination of functions*, such as sums, products and compositions. Students understand the *relationships between exponential and logarithmic functions* and the simplification of expressions using the trigonometric identities. Students use *mathematical models* to describe real-world phenomena and to solve real-world problems and understand the limitations of models in making predictions and drawing conclusions.

Students learn to use *linear models* for bivariate functions, exponential models for growth or decay, and periodic models with trigonometric functions. Students learn how to *organize data*, communicate the essential features of the data, and interpret the data in a meaningful way. Students express the *relationships* illustrated in graphical displays and tables clearly and correctly in words. Students write *solution sets correctly* with a number line graph by using interval notation and inequalities.

Students identify and express *characteristics of the graphs* of powers, polynomials, rational functions, exponential, and trigonometric functions. This includes increasing/decreasing intervals, curvature, local optima, long-term behavior of a relationship for given a function, a formula, or a graph.

All the learning outcomes are demonstrated by student-faculty contacts, allowing cooperation and conversations among students, encouraging active learning goals, giving prompt feedback early on their work, emphasizing completion of different tasks on time, stating high expectations and by respecting diverse talents and ways of learning. The assessment methods consist of homework and quizzes; midterm and final exams; project writing experience; student self-appraisal; and presentation. Each of these requires the student to integrate the body of knowledge on mathematical content of the course in relation to international issues and concerns which the student are being exposed to; reinforces lessons that may have not been emphasized in a regular course; offers opportunities for mature reflection on concepts and philosophical matters that the student would appreciate knowing; encourages the student to make explicit connections between the mathematics and the global issues; reiterates the importance of written and oral communication, and mathematical content; tests the student's ability to address a complex issue and/or a problem and produce new creative work; simulates the level of professional activity that the student will encounter in his/her career or in graduate-level study; increases the student's confidence in his/her ability to be an independent, life-long learner in the real world and to pursue a career that may need international awareness; and enriches the culture of creative discovery.

IV. CONCLUSION

The plan is to research, design, create and develop mathematical content in a math course related to global focus in accordance with students' level of mathematical understanding, then implemented and assessed. Students will learn the same mathematics that they traditionally need to learn, with a focus on global issues and international perspectives. Students will work on problems on these selected topics. At the end of the semester, the students will possess more diverse and knowledgeable view of the world, will have comprehended global dimensions, solved problems that arise in everyday life in different societies, and the workplace and hold global competencies throughout their life.

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The Requirements for an Electric Circuits Course in the "Modern" World

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***Abstract*— Electric Circuits is the first engineering course that students encounter in an electrical engineering programme and introduces them to Electrical Engineering and provides the required basic knowledge and skills. Between 1935 and 1965 engineering degrees changed from practical engineering to a more mathematical and model-based approach. In the 1980's there was a shift to "outcomes based" education and during the last decade there has been an emphasis on design. Since 2004 the author has been changing an Electrical Circuits course to improve throughput and better prepare the students for their other engineering courses. The changes have been in teaching methods and laboratory exercises and the content has remained traditional. Forty years ago engineering students had to solve problems and do the required mathematical procedures and were therefore trained as both an engineer and a computer. Now computers do the mathematical procedures. Each component of the Circuits Course was analysed. The results from this analysis indicate that the contents should essentially be left unchanged with more emphasis the understanding of current flow and voltage.**

Keywords—engineering education, electrical engineering, curriculum development.

I. Introduction

Electric Circuit courses are usually the first real engineering course that students encounter in an electrical engineering undergraduate degree programme. The aim of the courses are to introduce the students to Electrical Engineering, provide them with the basic knowledge and skills required for the rest of the programme and to develop an interest in the profession. A search of both course briefs [1], [2], [3] and circuit textbooks [4], [5] revealed that, internationally, the syllabi of electric circuits courses are essentially the same and have remained basically unchanged in the 40 years that the author has been involved in electrical engineering. A typical circuit course would cover: DC and AC concepts, basic components, energy, power, network theorems, circuit analysis, operational amplifiers and laboratory techniques. These basics are considered the foundation required to develop a successful electrical engineer.

Engineering education is continuously changing. Froyd et al [6] describe five major shifts in 100 years of engineering education. Between 1935 and 1965 engineering degrees changed from practical engineering to a more theoretical, mathematical and model-based approach. In the 1980's there was a shift to "outcomes based" education, formalised with the signing of the Washington accord in 1989 [7]. During the last ten years there has been a renewed emphasis on design in engineering curricula by re-introducing the more practical aspects of engineering.

Since 2004 the author [8] has been making continuous changes to the Electrical Circuits course, to improve throughput (retention) and better prepare the students for the engineering courses in their second and subsequent years. Throughput has become a major concern for the Government, and therefore the University administration, both in terms of financial constraints and the shortage of engineers in the country. The changes made were to develop conceptual thinking and engineering problem solving in students with a predominantly rote learning background. Changes in the laboratories were designed to encourage exploration rather than to just follow prescribed procedures. The results show an increased pass rate as well as reports that the students are better prepared for their second year of study.

The changes to the course were primarily in teaching methods and laboratory exercises and, essentially, the content has remained the same. What has changed, however, is that we don't use slide rules, calculators or do manual matrix calculations any more. Computers do that work for us now. Forty years ago engineering students had to solve problems and do the required mathematical procedures. As a result, they had to be trained as both an engineer and a computer.

Each component of the Circuits Course, in terms of the shifts in engineering education, the examination process and the students' marks was analysed. The results from this analysis, together with a justification for inclusion or removal of each component from the course, are presented. The justifications are not only based on whether the content is essential for successful engineering students or engineers, but whether they have any pedagogical value in the understanding of the essential basic knowledge and skills required for electrical engineering. There was no intention to replace any removed content with new content. The course is already very demanding, for first year students, and less content would give them more time to study and understand the basic concepts to be better prepared for their second year of study and, hopefully, increase the throughput.

II. Outcomes and Components of the Electric Circuits Course

The required outcomes that the students need to demonstrate to successfully complete the circuits course are:

TABLE I. CONTENTS OF THE CIRCUITS COURSE.

Basic concepts:	(70%-2012) (82%-2013)	Voltage, current, energy, power, resistance, independent and dependent voltage and current sources, charge and "average" values.
		Waveforms: DC, step, ramp, rectangular pulse, sinusoidal and exponential.
		Reactive components: Phasors, voltage-current (v-i) laws, energy and power relations and behaviour under excitation.
Analysis techniques:	(51%-2012) (57%-2013)	Ohm's law, Kirchhoff's laws, series and parallel resistors, voltage and current divider laws, star-delta transformations, Superposition theorem and interconnected sources.
		Real sources, Thévenin and Norton theorems, source transformation and maximum power transfer.
		Systematic analyses: Nodal, Loop and Mesh current analysis.
Laboratory techniques:	(60%-2012) (63%-2013)	Building circuits. Understanding of oscilloscopes, multi-meters, power supplies and signal generators. Analysis of results.
Complex Circuits:	(53%-2012) (69%-2013)	Operational Amplifier Circuits: Abstraction to circuit model, open loop gain, input resistance and output resistance. Analysis of inverting, non-inverting, buffer, summing, integrator and differentiator types. Calculation of gain and input and output impedance. Analysis of circuits with multiple amplifiers.

1) Using physical and mathematical modelling, determine the behaviour of the basic circuit elements;
2) describe and apply the principles encapsulated in laws and theorems;
3) analyse circuits by using formal methods;
4) simplify and transform circuits;
5) design and analyse circuits including an operational amplifier;

and have remained basically the same since 1989 when the present prescribed textbook was introduced, and was undoubtedly the same prior to 1989.

To prevent the students from optimising their learning by leaving out the "difficult" sections, vital for their further years of study, the course was divided into four knowledge areas, all of which have to be passed to the pass the course [8]. The four knowledge areas and their contents are shown in table I with the average class mark for each area. Prior to the introduction of the requirement to pass all the knowledge areas the students got the lowest marks in the sections covering AC theory (40% average) and operational amplifiers (49% average). As can be seen in table I the weakest area now is Analysis techniques and the analysis of the exam questions revealed that the lowest marks were obtained for Systematic analyses that contains content which in the "modern world" would be done using computer modelling or "number crunching" programmes.

III. Analysis and Results

A. Method

The analysis was done for each of the knowledge areas to classify the importance of the content and in terms of what the students need to "know" and what they need to "do" [9]. The information was gathered from discussions with lecturers of the courses requiring the knowledge and skills gained in the circuits course, determining the outcomes required for the degree programme [7] and investigating what is really necessary in the age of computers. From these results the contents was then divided into two classifications: "Untouchable" and "Let's see". The "Let's see" was further analysed by identifying the students' weakest areas, as defined by the marks obtained in the examinations, and whether there were pedagogical reasons for keeping the content. Removing the content that students struggle with will improve the pass rate for the course but not necessarily the throughput for the degree programme.

B. Results

Discussions with the lecturers were essentially unhelpful. Their response can be summed up as "We need everything and please add . . .". Although a first year course does not examine "exit outcomes" [7] it is important to note that content and skills that the students obtain from circuits courses are used as the foundation for the subsequent years leading to the examination of the students' "exit outcomes" in their final year.

The "Untouchable" classification covers all the content deemed essential for Electrical Engineering students and only requiring the use of a basic calculator to answer the exam questions. The course components that fell into this classification were Basic Concepts, Laboratory Techniques (examined both in the laboratory and in the exam) and Complex Circuits. This left only the Analysis Techniques component in the "Let's see" classification and it was also the component where the students got the lowest marks. Again the basic laws and theorems within this component were deemed to be essential in the training of electrical engineers requiring also very little computational skills from the students. This left the Systematic analysis sub-component, covering Nodal, Loop and Mesh current analysis techniques using the formation and manipulation of matrices, work probably best left to computers.

TABLE II. ANALYSIS OF EXAM SCRIPTS.

Year	Question	Average Mark %	% Passed
2012	Nodal analysis	19	14
n=28	Convert to matrix form	76	82
	Thévenin and Norton	8	11
2013	Nodal analysis	45	56
n=43	Mesh analysis	20	21
	Superposition	10	7

The exam scripts from 2012 and 2013 exams, for students who failed the exam, were analysed at individual question level for the Systematic analysis sub-component. In 2012 the question was nodal analysis and was divided into two parts (to simplify marking). Part one was to analyse a circuit and develop the simultaneous equations. Part two was to convert three simultaneous equations into matrix form. In the 2013 the students were required to analyse the same circuit using both nodal and mesh analysis by determining the simultaneous equations and then group the like terms to enable them to be entered into a matrix. Table II shows the results of the analysis.

Referring to table II: In 2012 the students did very well converting the simultaneous equations to matrix form, but poorly for the actual nodal analysis. After examining each of the 2013 scripts it became clear that the students were struggling with the determination of current flow in the nodes and meshes and not with the procedural problem of converting to matrix format. Understanding and implementing Kirchhoff's current and voltage laws are the basis of all electrical engineering. In 2013 the students did far better in the nodal analysis than they did in the mesh analysis. Mesh analysis is more abstract than nodal, again indicating a lack of understanding of current flow. The poor results for the Thévenin and Norton and Superposition questions also emphasise this lack of understanding of basic current flow. Examination of the Complex circuits component also revealed the lack of understanding of basic current and voltage laws. Plugging values into learnt formulae was no problem, determining the values was.

This brings up the last question: "Is there pedagogical reasons for keeping the content?". It became clear while examining the students scripts that Systematic analysis is the one area that examines the students' understanding of what current and voltage does. The actual conversion to matrices, also part of their mathematics course, indicates their ability to follow a procedure (being a computer) is not necessary in the understanding of electrical engineering. Pedagogically they need the practice and be examined on their understanding of the behaviour of voltage and current by undertaking Systematic analysis.

IV. CONCLUSION

The traditional content of an electric circuits course was investigated to determine which components were still necessary in the "Modern" world. The results indicate that even if some of the content may be "the work of computers" and not undertaken by engineers any more, there are important pedagogical reasons for including them in the course. The teaching and examination process could be changed to place more emphasis on understanding and less on procedural ability. Electrical Engineers still need to understand where current flows and where voltages are in a circuit.

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Teaching Technical Communications through Formative Assessment

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***Abstract*— Teaching the elements of effective communication to engineers can be challenging, yet is essential in their careers. In our second-year course, we teach (among other things) the basics of technical writing:**

- **How to locate and read the scientific literature**
- **How to format material professionally**
- **How to organise material logically**
- **How to time-manage producing a large document**
- **How to edit drafts (something often overlooked by time-crunched undergrads)**

We do this through a large term paper assignment. In the past, we felt that success in this endeavour was largely student-driven (rather than guided) and summative in evaluation. As a result, we implemented a number of formative assessment steps through the course of the term.

Because lecturing about the details of technical writing can be dull (for both instructor and student), we provide resources for the students to read. Online quizzes provide the incentive for students to keep up. In class, we strive to use workshops and in-class exercises to reinforce the lessons.

Small assignments throughout the term keep the students working consistently on this large paper and provide consistent feedback. These include:

- **A list of ten references relevant to their paper, formatted using Zotero (a free referencing tool).**
- **A proposed Table of Contents (properly formatted in Microsoft Word). Critiques are given online within a week by the instructor to ensure the student is on the right track early in their efforts.**
- **"Boss Quality" documents that include creating figures in Microsoft Excel and in drawing software and appropriate figure and table caption formats.**
- **A complete draft of their paper submitted to TurnItIn.com.**
- **Graded peer review of a paper (useful for reviewer and reviewee).**
- **Five-minute one-on-one meeting with the instructor or TA to highlight areas to improve in draft papers. Subsequent, longer meetings occur with students who are struggling at this stage**
- **Final paper due two weeks after draft to allow for editing.**

The results of this effort were higher quality papers (and higher grades), and, we feel, a more effective learning experience for the students.

Keywords—Technical Communication, Time Management, Formatting, Formative Assessment, Feedback;

I. Introduction

Teaching students the skills to communicate effectively is critically important to their future success, but is also very challenging. In Chemical Engineering at McMaster, we begin this journey in a second year course called Technical Communications and Problem Solving. We try to help students master the basics of technical writing, while incorporating lessons from the problem solving aspect of the course.

The course is unusual, in that it merges workshops developed by Don Woods [1] to teach problem solving fundamentals with technical communications. The synergy in material inspired us to make the in-class technical communications component also primarily workshop style as well.

The biggest assignment in the class is a technical paper. The paper is 1500-2000 words and each student chooses their topic from an extensive list. The students have always struggled with managing their time appropriately to finish this, so we decided to break up the task into smaller, more achievable sub-goals. We will describe the sub-assignments in detail.

A key part of the success of this assignment has been the formative assessment used throughout. The students receive timely feedback throughout the term on their chosen references, their outline and a draft of their final paper. This, combined with use of TurnItIn.com has improved the quality of the final submissions and reduced plagiarism.

While we are still striving to improve the student experience, we feel this step-wise, interactive formative approach has been a success.

II. Course Content

The second year course in Technical Communications and Problem Solving merges two seemingly disparate components. The objectives of the technical communications component of the course include:

- Understanding the difference between peer-reviewed literature (review and research articles) and less credible sources, including Wikipedia and websites
- Learning how to search for relevant research articles
- Distilling large quantities of information into a clear, logical and well-organised "story"
- Using concise, precise language
- Formatting documents professionally
- Addressing the appropriate audience
- Avoiding plagiarism through proper referencing and paraphrasing
- Practicing written and oral communications

The objectives of the problem solving portion of the course include:

- Ability to talk through and reflect on thought processes while solving problems
- Self-assessment ability with regards to performance based on goals, measurable criteria and evidence
- Ability to give and receive feedback
- Analysis and classification of complicated information
- Time and stress management
- Creativity in approaching problems

Clearly, the problem solving component of the course is useful in addressing the issues of a term paper. In particular, we emphasise goal-setting, feedback, analysis and classification and time management.

III. Delivery of Course Material

We have moved from delivering the technical communications material primarily in lectures to workshops. The consequence of this shift is that the material is not delivered in detail during class time. We chose to assign specific readings for each week. To ensure the students are prepared for class, they are given weekly online quizzes that cover the pre-readings. Although we suspect collaboration, the pass rate and participation on the quizzes were nearly 100%. During the classes, a short introductory lecture was given, and then the students were assigned specific tasks.

For example, in pre-reading, the students learned about pyramid-style writing. In class, we gave the students several examples of introductions, and asked them, in pairs, to critique them. After discussing the critiques as a class, the students then re-wrote the introductions. This active practice of skills resulted in better introductions in their final papers.

IV. Assessment

The term paper is a major component of the course, worth 28% of the final mark. In the past, the primary reason students gave for very poorly written or plagiarised papers was procrastination. This was an ideal opportunity to put into practice the skills learned in the problem solving workshops on time management and self-assessment. In particular, we get the students to break the goal of "writing the term paper" into measurable and unambiguous sub-goals (e.g. "Using Pubmed, find at least ten peer-reviewed research papers relevant to my topic"). We use this concept of sub-goals to break down the term paper task into achievable, smaller assignments.

A. *Assignments*

Some of the assignments are a direct component of the term paper; others build the skills to complete it.

Quizzes: 4% of final grade. These online quizzes give a marks incentive to students to read assigned resource material prior to doing in-class workshops (flipping the classroom).

Problem solving workshop – Self-Assessment: 4% of final grade. As a component of this workshop, the students must break down the large task of completing a term paper (goal) into short-term achievable "chunks" (measurable, unambiguous sub-goals).

Literature search: 1% of final grade. Students must hand in a list of ten articles relevant to their topic. The list must be created using a free and open-source referencing tool, Zotero. Many students tell us later that this was the most valuable skill they learned!

Article summary: 1% of final grade. Finding the relevant literature is one thing; understanding it is another. The students must choose a research paper and summarise it in lay language. This teaches conciseness, audience analysis and reading literature with high-level scientific language.

Problem-solving workshop – Analysis and Classification: 4% of final grade. The students are required to create an outline for their paper well before it is due. During the workshop, they learn how to critique it structurally (e.g. there must be more than one sub-section). Subsequently, they submit their revised outline electronically. This is a key checkpoint in the process. In one week or less, the instructor(s) (not TAs) provide a written critique of the content of their outline with constructive suggestions. In some cases, we identify students who need to come in for a one-on-one conversation, as they are clearly struggling with their topic. This has been a very productive, formative assessment. As a result of this, the number of very poor papers has dropped dramatically.

Proofreading activity: 1% of final grade. To give the students some skill in grammar and editing, we do an in-class workshop to help them identify and correct common grammar errors.

Boss-quality documents: 2 assignments worth 3% each. These assignments give students the skills they need to use software properly and present material professionally. They must demonstrate proficiency in drawing software of their choice. We provide a list of freeware alternatives, and they must exactly reproduce a diagram we provide. They must also demonstrate that they can use Microsoft Word and Excel to properly produce and label graphs and tables. Including these assignments has decreased the basic formatting mistakes that used to be common in the term papers.

Plagiarism statement: 1% of final grade. We do a workshop in which we discuss plagiarism and proper referencing. As a component, students must write a definition (in their own words) of plagiarism, attest that they will not plagiarise and sign and date it. This highlights the importance to the students, and provides us with documentation if there are any subsequent problems (even in upper year courses).

Draft of the term paper: 3% of final grade. The students must submit a complete draft of their paper to TurnItIn.com two weeks prior to the final due date for the paper. This serves two purposes: it ensures that the procrastinators have a two week buffer to complete their paper and allows times for review and editing.

Peer review of the term paper: 4% of final grade. The TurnItIn.com software automatically and anonymously allocates papers for peer review. We have found this is helpful to the reviewer, as it gives them an opportunity to critically assess a peer's paper, which in turn gives insight into potential improvements on their own paper. It is generally helpful to the reviewed student, as most students leave very thorough comments throughout the paper. Indeed, many of the peer graded papers are assessed more thoroughly than we as instructors would have time to do ourselves.

Instructor review of term paper (grade included under draft of term paper assignment). Each student is given a five minute appointment with an instructor or TA to briefly go over their draft paper. Students bring hard copies to the meeting. We have found that these very brief meetings are adequate to catch most major problems and suggest areas of improvement that the students follow through on. Occasionally, students will require a longer, subsequent appointment to discuss way to improve their paper to our standards. This one-on-one formative assessment has been extremely useful in improving the quality of papers, and we believe, the technical writing skills in our students. In many ways, this is a more effective assessment than the final, graded copy that the students receive at the end of the term. Previously, we experimented with grading a draft and a final copy, but the grading was extremely time-consuming for the instructors, and of no more value than these brief meetings.

Oral presentation: 8% of final grade. The ability to present material orally is obviously valuable. Beyond that, we find that condensing the material to make an effective presentation helps students see whether they are telling an effective story. In some cases, students will re-organise their paper. We provide the students with digital video files of their presentations, which they have to self-critique. Peer grading is also a component of the final mark.

Final term paper grading: 20% of final grade. The grading of the term paper is done according to a very descriptive rubric that is given to the students in advance. The rubric is provided in the next section.

B. *Term Paper Marking Rubric*

The detailed marking rubric is not reproduced here in its entirety due to space limitations. At each level (A – F, where A = 90%, B = 70%, C = 50%, D = 30% and F = 10%), we give a detailed description of the expectations to achieve that level. For example, under Quality and Clarity of the Argument, to achieve an A, we specify: Discussion of topic is covered in a way which shows depth of analysis, exploration and synthesis of information, and not superficial reporting of facts. Our rubric was adapted from Fielding [2]. In previous years, we used a more standard, less detailed marking scheme that was open to inconsistency and bias. Students were often confused about the expectations. Since adopting this detailed rubric, we have had fewer students asking for clarification on why they received a given grade.

Table I. Term Paper Marking Categories

Structure and Appearance of Report (i.e. what the report looks like. Figures and Tables are useful and labelled correctly; page numbers are correct; Table of Contents is proper; sections are clearly structured and logical.)	10%
Readability and Technical Writing: (How easy is it to read and understand this report? Writing is pyramid style; meaning is clear, concise and precise.)	10%
Quality of the Abstract: (The abstract should tell me why I need to read this, what I will learn and tell me the important conclusions. It must be stand-alone.)	10%
Quality of Introduction: (The introduction should tell me what the question is, and provide historical context)	10%
Quality of Technical Content: (Covers the state of the art in the area and should reference current literature. Correct, current, thorough, high technical level)	10%
Quality and Clarity of Argument: (This is basically "enjoyability". The paper should have a good narrative (story) that ties the report together making even complex topics easier to understand.)	10%
Quality of Overall Analysis and Conclusions: (A conclusion should summarize and analyze what has been learned in order to synthesize and address answers to the questions asked in the introduction. Should also discuss any limitations to the report and possibly suggest further work.)	10%
Quality of Cited Literature: (The best literature comes from primary peer-reviewed sources and should be up-to-date.)	10%
Correct use of Citations/References/ Bibliography (Zotero used properly; references provided at appropriate points in the text)	10%
Checklist complete (We provide a checklist that specifies many of the formatting requirements of the paper)	10%

C. Collaborative editing

We feel the real strength of our approach lies in the collaborative process throughout the term. By giving feedback throughout the process and encouraging editing, the students not only produce an improved final document, but they understand the expectations of a technical report better. Prior to this change, the marking process was often frustrating, as we would deduct grades for issues both large and small that we had covered during lecture time. For example, some students clearly simply did not understand their complex technical topic. In other cases, the students previously often mislabeled figures and tables. By addressing these issues earlier in the term, we reduce the dissatisfaction experienced both by instructors and students. The critiques of outlines are particularly effective in helping those students who struggle with the technical complexity of the topic. Meeting about the draft of the paper is also highly effective on two counts: it gives a chance to procrastinators, and, even in the very brief (five minute) meetings, it gives guidance to the students on how to improve. The students really appreciate the personal interaction with the instructors and take the advice to heart. The editing process is something that is often neglected in the undergraduate experience, but is very important in their later career.

D. Plagiarism prevention

We have used TurnItIn.com for several years, with good success. The students are allowed to submit their papers in advance and view their own Originality Reports. We have also discussed proper referencing, plagiarism and required the signed plagiarism contract for several years. These activities reduced plagiarism from 10-20% of the class to 1-2%. We feel that our formative approach has virtually eliminated plagiarism. Because we give feedback throughout the process, it makes it extremely difficult for students to purchase papers online. In addition, the draft document gives the instructor and student the opportunity to constructively address improper referencing and quotation prior to the final evaluation. Further, the requirement that the paper be completed in draft form two weeks prior to the final due date removes the stress of procrastination, which is often cited by students as motivation to plagiarise.

V. Conclusions

The term paper is frequently assigned as a component of technical writing courses. Too often, it is simply an evaluation of the existing ability of students. We have tried to make the term paper into a valuable learning experience by breaking it down into smaller tasks and providing timely feedback throughout the writing process. We believe this has helped our students internalise lessons about how to do literature searches, how to read scientific literature, how to organise complex information, how to write accurately and concisely and how to format technical reports properly. Our interactive, workshop-based approach keeps the students engaged and actively learning.

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Laboratory Scaled Plug-in Electric Vehicles Car Park Infrastructure Emulator Design

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***Abstract*—In this paper, the methodology of how to design a laboratory scaled plug-in electric vehicles (PEVs) car park infrastructure emulator is presented. The PEVs car park emulator can be viewed as a hybrid micro grid that contains both AC and DC side. Five lithium-ion battery banks are used to act as five PEVs in the car park. The charging/discharging power rate of each individual battery is regulated by its bidirectional DC-DC converter, which can be viewed as the charger for the PEVs. A bidirectional AC-DC converter is used to connect the car park to the utility grid. Based on the system power balancing and load variation situations in AC and DC sides, the power flow through the bidirectional DC-DC converter and AC-DC converter can be adjusted to keep the system stable. Different control algorithms for power electronic devices such as wireless control of bidirectional DC-DC converter power flow can be tested in this micro grid. Also, several concepts such as the vehicle to grid (V2G), vehicle to vehicle (V2V) and vehicle to house (V2H) services can be simulated on this platform. In this presented design, Matlab Simulink and TeraTerm Pro are used in conjunction with the STM32F4DISCOVERY microcontroller, DSPACE controller and XBEE transceivers. The proposed car park infrastructure emulator can be used for both research and educational purposes. The end result of this design is to give the students a platform where they can learn about hybrid micro grids and test novel ideas involving the future applications of PEVs to power systems.**

***Keywords*—Hybrid Micro Grid, Micro Controller, Lithium-ion Battery, Plug-in Electric Vehicles, Power Electronics.**

I. Introduction

Plug-in electric vehicles (PEVs) are gaining popularity due to the increasing need for clean energy worldwide. Fossil fuels as energy resources are becoming scarce and have already led to worldwide issues at the environmental, industrial, economic, and societal levels [1]. At the same time, owing to strict power quality and systems reliability requirements, the need of distributed generation (DG) and the implementation of micro grids (MG) are heightened [2-3].

However, the increasing number of PEVs may have a serious impact on the electric utility if properly designed smart charging techniques are not utilized. Uncoordinated and random charging activities could greatly stress the distribution system, causing several kinds of technical and economic issues because of network overloads. On the other hand, PEVs can be viewed as energy storages when they are parked in the car park for a long period. In this case, they can cooperate together to help the utility grid improve the power quality through some vehicles to grid (V2G) services, such as grid frequency regulation, voltage regulation, spinning reserve, reactive power compensation and so on [4]. Also, smartly control the power flow from vehicle to vehicle (V2V) and vehicle to house (V2H) can greatly limit the charging impact to the utility grid and improve the local micro grid power quality [5].

From the above, it is of the utmost importance to teach power systems engineering students how to smooth control the charging process of the PEVs, how to implement the V2G, V2V and V2H with power electronic devices, such as bidirectional AC-DC and DC-DC converters, and how to monitor and control the power flow across a micro grid. Therefore, a laboratory based micro grid platform should be established for power systems engineering students to test and verify different PEVs smart charging algorithms together with control methods for different power electronic devices that are essential in future power systems.

In this paper, the methodology of how to establish a laboratory scaled PEVs car park infrastructure emulator will be presented. Five lithium-ion batteries are used to emulate the behaviors of five individual PEVs. The process involved in developing power electronics devices that work together with the batteries to maintain system stability and reliability will also be detailed. The utilization of microcontrollers to allow for the control of power flow between the micro grid and PEV car park emulator will also be explained. This methodology is presented to the student as a hands-on engineering solution to the need for a plug-in electric vehicle parking lot that serves to charge and discharge the battery of each vehicle through a bidirectional DC-DC buck-boost converter while it is parked. This vehicle parking lot can be directly connected to the AC utility grid through a bidirectional AC-DC converter to not only charge vehicles, but to serve as an energy storage device to increase the stability of the utility grid by supplying additional power during high demand. By applying the active power and reactive power decoupling technique to the bidirectional AC-DC inverter, some V2G emulation will be demonstrated to students.

The paper is organized as follows; the overall system description together with the description of the components that are needed to build the PEVs car park emulator is given in section II. Power electronics devices and filters that are used to establish the PEVs car park emulator are given in section III. Different control strategies to fulfill the V2G, V2V and V2H by using several micro controllers are described in section IV and concluding remarks are provided in section V.

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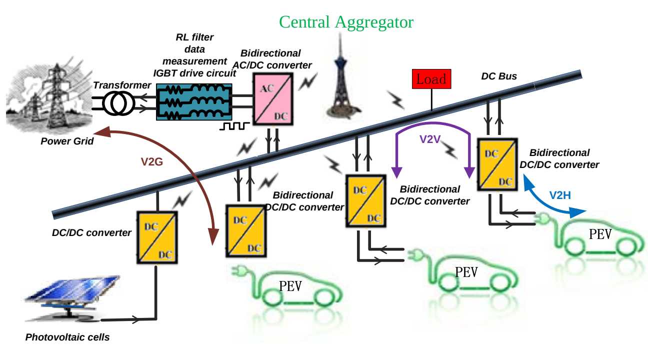

Fig. 1 Abstract diagram of the hybrid AC/DC system with wireless control.

II. SYSTEM DESCRIPTION

The diagram of a hybrid PEVs car park micro grid is shown in Fig. 1. To be more specific, it has both an AC side and a DC side. The PEVs are connected to the DC bus of the micro grid through a bidirectional DC-DC inverter. A Solar energy panel is also connected to the DC bus through a DC-DC converter with maximum power point tracking (MPPT) function. The DC bus is connected to the utility grid through a bidirectional AC-DC inverter. Different kinds of loads can be connected to either the AC or DC side. There is a central aggregator which monitors the micro grid and sends control signals wirelessly to different power electronic devices to manage the power flow in the hybrid micro grid. As shown in Fig. 1, energy can be transferred from utility to the PEVs or vice versa through V2G services. This process can be viewed as the battery charging/discharging process. Also, energy can be transferred between different PEVs, which are known as V2V services. Moreover, if the DC bus is over loaded or has over voltage, the energy can be injected or absorbed by the PEVs through the V2H function.

Based on the configuration shown in Fig. 1, the components

TABLE I
PEVS CAR PARK EMULATOR COMPONENTS

Components	Functions
Battery banks	Act as PEVs
Bidirectional DC-DC converters	Regulate the power flow between the DC bus and the batter banks.
Bi-directional AC-DC inverters	Regulate the power flow between the DC bus and the AC bus.*5mH*
Transformer and power filter	Connect the AC bus to the utility Collect the voltage and current to monitor the stage of the micro grid.
Voltage and current transducers	Collect the voltage and current to monitor the stage of the micro grid.
Micro controllers	Control the power electronic devices to regulate the power flows.
Wireless communication devices	Remote wirelessly monitor and control the system.
Relays and fuses	Protect the system.
PC	Act as the central aggregator.

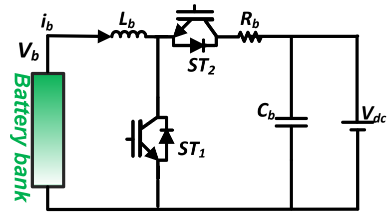

Fig. 2. Topology of bidirectional DC-DC converter.

that are needed to establish a hybrid PEVs micro grid car park emulator and their functions are given in Table I.

In this paper, five Lithium-ion battery banks are used to emulate five individual PEVs. They are connected to the common DC bus through five bidirectional DC-DC converters, respectively. Five STM32F4 DISCOVERY micro controllers are used to regulate the current flow in the five DC-DC converters, and the reference current signals are sent to the micro controller through wireless communication by using XBEE transceivers. In the AC side, a three phase bidirectional AC-DC inverter is used to control the power flow between the AC and DC side. DSPACE-CP1104 is used as the controller to regulate the power flow through the bidirectional AC-DC inverter. The parameters of all the components are shown in Table II.

TABLE II
HYBRID MICRO GRID SYSTEM PARAMETERS

Symbol	Description	Value
C_{pv}	Solar panel capacitor	*100 uF*
L_{pv}	Inductor for solar Panel boost converter	*5mH*
C_d	DC bus capacitor	*6000 uF*
L_{ac}	AC filter inductor	*1.2mH*
R_{ac}	Inverter equivalent resistance	*0.3ohm*
L_b	Battery converter inductor	*3.3mH*
R_b	Resistance of L_b	*0.5 Ω*
f	Rated AC grid frequency	*60Hz*
V_d	Rated DC bus voltage	*300V*
Vm	Rated AC bus p-p voltage (rms)	*208K*
$n1/n2$	Transformer ratio	*1:1*

III. POWER ELECTRONICS DEVICES AND FILTERS

The most essential power electronics in the PEVs car park infrastructure emulator are the bidirectional DC-DC and AC-DC converters.

A. *Bidirectional DC-DC inverter*

The topology of the bidirectional DC-DC converter is shown in Fig. 2. It is a current controlled converter that can function in both boost and buck modes. The battery banks are connected to the low voltage side, and the high voltage side of the converter is connected to the DC bus. By controlling the IGBT switch S1, the converter can be operated in boost mode. The current flows from the battery bank to the DC bus and the battery bank is discharged. In buck mode, only IGBT switch S2 is used. The current flows from the DC bus to the battery bank and the battery bank is charged.

The PCB based bidirectional DC-DC converter circuit board is shown in Fig. 3. It has two IGBTs together with the

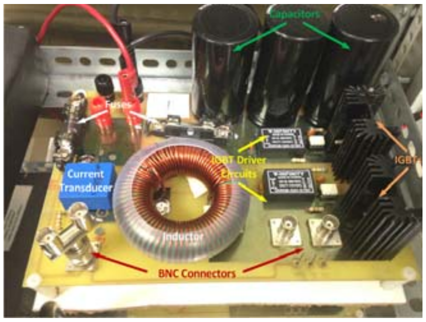

Fig. 3. Bidirectional DC-DC converter circuit board.

IGBT driver circuit. On the high voltage side, three 450v 1200 μF capacitors are connected in parallel to limit the high voltage side voltage variation. On the low voltage side, a $3.3mH$ inductor is used to boost the voltage and filter the current flow through the converter.

B. Bidirectional AC-DC inverter

The topology of the three phase bidirectional AC-DC inverter together with the RC filter and the transformer are shown in Fig. 4. Equations (1) and (2) show the AC side voltage equations of the bidirectional AC/DC inverter in ABC and *d-q* coordinates, respectively. Where (V_a, V_b, V_c) are AC side voltages of the inverter, and (E_a, E_b, E_c) are the voltages of the AC bus. (Δ_a, Δ_b, Δ_c) are the adjusting signals after the PI controller in the current control loop.

$$L_{ac}\frac{d}{dt}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + R_{ac}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} - \begin{bmatrix} E_a \\ E_b \\ E_c \end{bmatrix} + \begin{bmatrix} \Delta_a \\ \Delta_b \\ \Delta_c \end{bmatrix} \tag{1}$$

$$L_{ac}\frac{d}{dt}\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} -R_{ac} & \omega L_{ac} \\ -\omega L_{ac} & -R_{ac} \end{bmatrix}\begin{bmatrix} i_d \\ i_q \end{bmatrix} + \begin{bmatrix} V_d \\ V_q \end{bmatrix} - \begin{bmatrix} E_d \\ E_q \end{bmatrix} + \begin{bmatrix} \Delta_d \\ \Delta_q \end{bmatrix} \tag{2}$$

The hardware of the bidirectional AC-DC inverter together with the AC filter and the transformer is shown in Fig. 5. The AC-DC inverter has 6 IGBTs, each two controls one phase. With the Park transform, the active power and reactive power transferred through the AC-DC inverter can be easily controlled by regulating i_d and i_q. In this way, both active and reactive power flow can be controlled.

IV. MICROCONTROLLERS AND CONTROL STRATEGIES

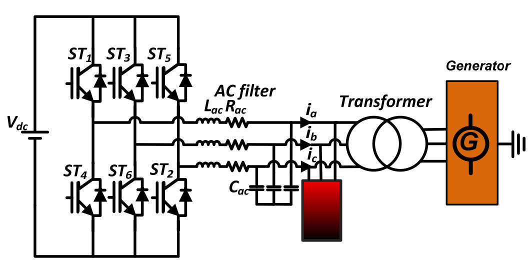

Fig.4 Topology of three-phase bidirectional DC-DC converter.

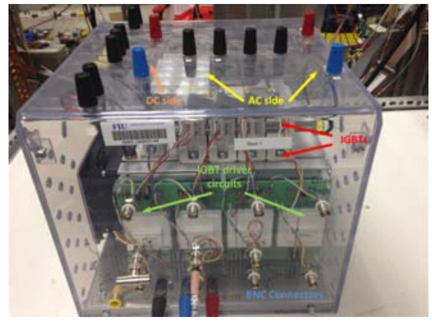

Fig. 5. Bidirectional AC-DC inverter hardware.

A. Microcontrollers

STM32F4 DISCOVERY microcontrollers are used to regulate the power flow through the bidirectional DC-DC inverter in the PEVs car park emulator. There are five battery banks and five bidirectional DC-DC converters that are used to emulate five individual PEVs. Five of these microcontrollers are used to control the power flow through each bidirectional DC-DC converter. Based on the SOC of each PEV, unique charging/discharging signals are sent from a central computer to the STM32F4 DISCOVERY through wireless communication by using XBEE wireless transmitters. In this way, the V2V service and V2H service can be fulfilled. The transmitters can also work in broadcast mode, which will synchronize all the five battery banks and make them work together. The wireless cooperative control of the five bidirectional DC-DC converters is shown in Fig. 6.

DSPACE CP1104 is used to control the active and reactive power flow in the AC-DC inverter. By adjusting the i_d and i_q reference signals, both active and reactive power flow can be controlled through the AC-DC inverter to regulate the AC side frequency and voltage, which can emulate the V2G functions of the future PEVs car park.

B. Control Strategies

If the hybrid power system AC side is connected to a robust AC utility grid such as a university's grid, then the frequency and voltage amplitude can be viewed as constant and no V2G services are needed. In this case, the bidirectional AC-DC inverter will take charge to regulate the DC bus voltage. The control block diagram for the bidirectional AC-DC inverter is

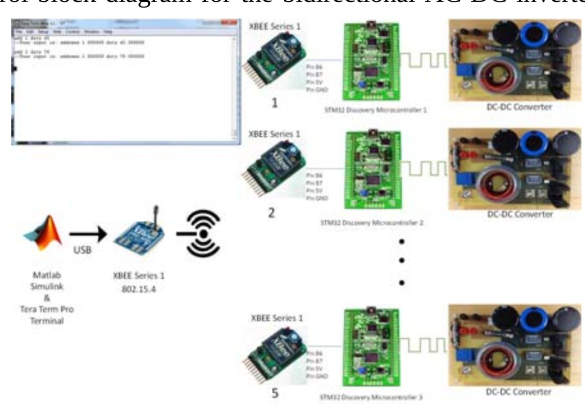

Fig. 6 Wireless cooperative control of charging/discharging of five battery banks.

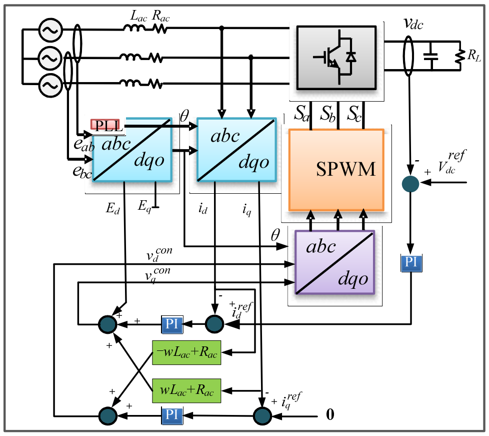

Fig. 7 Control block diagram for bidirectional AC/DC converter in grid-connected mode.

shown in Fig. 7. The five battery banks charging/discharging rates are regulated by their DC-DC inverters. For example, if all the charging rates are positive, then power flows from DC bus to the battery banks. Because of this, the DC bus voltage will drop. After sensing the DC voltage drop, the AC-DC inverter will transfer power from the AC side to the DC bus to keep the DC bus voltage stable. In this way, the energy is transferred from the utility grid to the battery banks and the battery banks are charged. On the other hand, the battery banks can be charged/discharged with different charging ratios. For example No.1 battery bank charging rate is 5A and the No.2 battery bank charging rate is -5A, in this way the energy is transferred from one battery bank to the other one, and this process can be viewed as V2V function.

If the hybrid power system AC side is connected a system that is not so robust such as a islanding power system, then the AC side frequency and voltage need to be regulated. In this case, the bidirectional AC-DC inverter will take charge to regulate the AC bus frequency and voltage. The control block diagram for the bidirectional AC-DC inverter is shown in Fig. 8. The five battery banks are responsible for regulating the DC bus voltage. For example, when the AC side frequency drops, the bidirectional AC-DC inverter will sense this and increase the i_d reference, which will increase the active power flow through the AC-DC inverter from the DC bus to the AC side and increase the AC side frequency back to the normal value. Since the energy is being transferred from the DC side to the AC side, the DC bus voltage will drop and the five DC-DC converters will sense the DC bus voltage drop and increasing the discharging rates, which will force the DC-DC converters to increase the power flow from the battery banks to the DC bus. In the end, the energy is transferred from battery banks to the AC grid to support the frequency regulation. This process can be used to emulate the V2G services of the future PEVs car park. Also, if a local load is connected to the DC bus, the DC bus voltage will drop, which will cause the DC-DC converter to send power from the battery banks to the DC bus. This process transfers energy from the battery banks to the local load which emulates the V2H services.

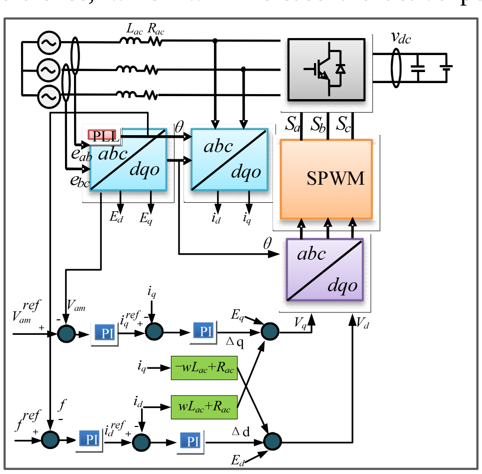

Fig. 8 Control block diagram for bidirectional AC/DC converter in islanding mode.

V. Conclusion

This paper describes the methodology of using power electronic devices and micro controllers to establish a PEVs car park infrastructure emulator platform that can be used both for teaching and research. This PEVs car park infrastructure is a hybrid power system that contains both AC and DC sides. Cooperative control of the power electronic devices can transfer energy from AC side to the DC side and vice versa. Several novel concepts such as the V2G services, V2V services, V2H service, frequency regulation and voltage regulation can be tested in this platform. The methodology encompasses numerous educational aspects that teach the undergraduate student a myriad of engineering concepts, all essential to his/her success as an engineer. Upon completing this methodology with the instructor, the student will have been introduced to power electronics concepts such as micro grids, plug-in electric vehicles, power flow, and devices such as bidirectional converters. The student has also familiarized themselves with the fundamentals of Matlab Simulink and has gained a greater understanding of microcontrollers and how they can be utilized to control power electronics devices on a basic level. The student should be able to reflect on all of these new and interesting engineering concepts in a very positive light since they were able to apply it themselves to a real world problem that will be prevalent in the foreseeable future with the continuous growth in electric vehicles and hybrid micro grids implementing energy storage devices.

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Flipping the Design of a Classroom

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Abstract−This paper describes the flipping of the design process for a classroom whereby the users (students) did the design.

Keyword−classroom design, user centered design

I. INTRODUCTION

An interdisciplinary student group run out of an engineering design program did the redesign for a rapid conversion of a computer lab to a design studio classroom in 2013, hereafter referred to as 316H. It is part of an eight-classroom and lab learning center, The Center for Engineering Design and Entrepreneurship. (CEDE) [1]

This article reports an assessment of their design in use. The group, in previous incarnations, had been making redesign proposals to various clients on Penn State's University Park campus for about 5 years, always resulting in some degree of realization. For example, the group's recommendation to move from portrait to landscape seating configurations, which allowed banking and dual screens for better visibility, has been adopted in numerous classrooms along with colorful rooms, lower student density, and improved ADA/human variability compliance.

This current student design team embraced user-centered design and interviewed and surveyed faculty members and students about their needs for a classroom that would be used primarily to teach sections of 32 students in an introductory design course required of almost all engineering students. Their work led to a renovation and repurposing of the room over the summer of 2013. Almost all of their ideas were implemented and the room was ready for classes in the fall of 2103. The students received academic credit.

The final design features eight design pods placed along the sides of the room with entry at the end and a windowed, north-light wall at the other. Two screens are opposite each other at the midpoint of the side walls. The typically display the same thing. The small podium is alongside one of the screens. A narrow table along the wall provides space for two computers and a power strip. An orthogonally placed table on wheels with two chairs on each side and one at the end complete the pod. All five chairs have wheels. Both side walls were skinned with a white dry erase surface. A slate chalk board in excellent condition was left along the end wall. This happened during the realization stage at the request of several faculty members. The ceiling, lighting, and floors were all renovated. The room impresses with its wide open central space. (Fig. 1. Before and After)

Before and After

Fig. 1. Before and After

II. THE DESIGN PROCESS

The design process was open and even the client (department head, also responsible for the realization process) requirements changed significantly during the process. The assumption was that as long as the process was open and that it engaged the users, the design outcome would be good. However, since user-centered design is inclined to miss innovative solutions, the team also benchmarked extensively on campus and globally. Despite this benchmarking, the team largely missed the literature for current thinking on classroom design and we will invert the usual paper format and use a limited literature review, which has been done since the design, as one means to

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1. Undergraduate engineering student design team in spring 2013
2. Instructor in architectural design
3. Professor of Engineering Design

assess the quality of the design. The team used a website to organize their work. [2]

As a result of this design process, the team found some very different ideas and needs for the classroom among the users. They soon realized that this classroom should be readily convertible. They needed a classroom that could be changed for each class, and thus they obviated any need for training faculty for new classroom environments. We used several strategies to achieve this, one being to put all tables and chairs on wheels allowing a rapid reconfiguration in about half a minute for any given class. This ancient Sumerian invention (the wheel) just keeps on giving.

Few faculty members have had problems adjusting their teaching style and some welcome the chance to get a room layout more amenable to their pedagogical style. One peripatetic faculty member teaching simulation in a graduate class was delighted to realize that he could stand in the middle of the room, where he was anyway, and watch members all the simulations running. The room for some faculty becomes a 360-degree, podium-free, teaching space with no preset orientation. Some other faculty members remain traditional. New uses keep appearing that were never thought of during the design. Two classes combined to do a design poster exhibit for 16 teams. And one frequent guest professor likes to rearrange the furniture himself before class, which takes about 5 minutes.

The primary functional need was for a design studio that houses 32 students and is almost always configured in eight teams of four. So the team made the room design-pod centric. Students walk into the room and go straight to their design team pod and their team members. The students sit opposite each other in these pods to promote conversation, and each pod has two computers in support.

We need to know how well this works in terms of acceptance by students and faculty, and whether performance metrics would show gains relative to the existing design studios, which have wheel-less tables, conventional, unidirectional seating, and are without computers. Only our two computer labs use design pod seating arrangements. This allows us to use a three way comparison for design work outcomes.

Another need was social acceptance/ affective design. We assumed (emotions) that a positive emotional response to the room will enhance performance in the room, and that user centered design would promote good affective design. Aesthetics are a part of this just as it is in industrial design. And so, too, is convenience, which is comparable to usability in industrial design. So we placed the design pods around the walls of the room and created a large open space in the center. Our assessment examined how welcoming and convenient this is for students and faculty.

The assessment goals were to measure the success in achieving the design goals of flexibility, enhanced team performance, communication (student-student and student-instructor), convenience, and affective bonding. The results were a strong affirmation of the design using these metrics. However, at this point we are still relying on user perception and not performance measures.

III. USER CENTERED DESIGN

There is a considerable literature on user centered design [3, 4] and “lead user centered” design that is far more important for innovative design [5]. And see the related ISO standard on usability "The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use." [6]

There are obvious benefits to using UCD. Improving the return on the investment (ROI) being one of them. Charette’s extensive review of case studies of major software failures leads him to conclude “In IT projects, an organization that values openness, honesty, communication, and collaboration is more apt to find and resolve mistakes early enough that rework doesn't become overwhelming.” [7] UCD and participant design are good ways of achieving this and the team represented both.

We make a point of stressing UCD because typically the universities do not include students when doing classroom design, even when they have been innovative.

IV. LITERATURE REVIEW

The literature on classroom design was recently summarized by faculty-staff groups at Princeton University in 2013 [8], and at Georgia Tech in 2009 [9]. The student design reported here was inadvertently done without the benefit of these reports. Their design, however, is strongly supported by the findings of these two study groups.

The Georgia Tech report concluded that good classroom design should embrace five principles. The classrooms should facilitate student engagement, student collaborations, and connections between students and teachers. The students achieved these three goals and the report’s support of movable tables and chairs, wide aisles, breakout spaces (team pods), visible students and display surfaces reads like a description of the 316H design in use. The report also proposed appropriate technology listing features that are all available in 316H, except for printing that is currently only available next door and that will change. The report stresses the need for a flexible classroom physical arrangement, and this is perhaps the most defining feature of 316H.

The Princeton report is a longer document and its recommendations overlap those of the Georgia Tech Report. Differences include stressing natural light (affective design), flat floors (design for ADA, convenience, and maintenance), walls prepared for presentations from markups to screens, healthy durable materials. The student design did the second and third of these.

Had the student team read these reports first they would have become dependent upon them. To read them now is a reaffirmation of what they did, and a good touchstone for when the design is reviewed again in a few years.

V. ASSESSMENT METHODS

The assessment framework used is provided below. It addresses the four main design categories: a flexibility, communication functionality, affective engagement, and infrastructure. We surveyed the students using Google Forms in Docs. The survey had 28 questions and took about 5 minutes to complete relying heavily on multiple-choice, Likert scales. There were 5 questions with reverse scoring.

VI. SURVEY RESULTS

The data reported here are student data and it reports their perceptions. We have not yet developed performance measures, even though these would be a confirmation that this design is not just liked, but it leads to higher productivity, qualitatively and quantitatively.

We received 86 responses to an online survey of students. Roughly one third of which came each from Devon's class, from the main critic's class, and from a mass email to the ~530 students enrolled in the 17 sections of the course who used 316H. By chance, these three sets of responses came in at different times and can be separately evaluated.

We asked students about their interest in how classrooms were designed. We found that 20% were very interested and 30% somewhat interested. However, if student interest were more widely solicited and cultivated, these numbers would grow.

A lot of students responded to queries about the best and worst features of 316H. Most mentioned the pod design, the visibility of the opposing screens, the movable furniture, and the wide open central room space as desirable features.

The most frequent negative comments were bad viewing angles for the extreme four pod locations (the chairs have wheels, but students tend not to move to a better position), not enough computers (there are two per pod of four students), hard to track the instructor, and wasted space in the middle of the room. Others noted that the pod white boards were a bit inaccessible (somewhat true), the chairs are smelly (they will be cleaned), and cold desktops. Other complaints mentioned the A/C and the building itself some truth in both). However, most of these comments were not supported by detailed questions.

Despite the criticisms in the comments, only 6% registered a dislike of 316H, whereas 22% really liked, and 48% liked, 316H. And 70% agreed that they really liked the flexible space. Only 15% felt their instructor was uncomfortable in the room and half thought they were more comfortable.

In contrast to the comments about the wasted space only 1% disagreed with the statement "I like the wide open welcoming space of the room. I feel good walking into it," whereas 77% agreed with this statement. And 92% agreed that 316H "felt more spacious even though it is the same size as most other CEDE classrooms." Also, 79% agreed that they "like the way we enter the room and sit with our teams," as opposed to the usual awkward scrambling for a row seat often among strangers. Only 6% disagreed with "I look forward to classes in 316 Hammond. I wish we had more classrooms like it." All these findings suggest that the attempt to achieve a good affective design worked.

About half the students, 51%, thought student-instructor communication was not good in the room, but 30% disagreed. On the other hand, 59% thought student-student communication was good, but 22% did not agree. This suggests we need to work on student-instructor communication, although that may improve as faculty members adjust to the room.

Screen visibility was a major issue during the design that was solved by a student team member who had had a class with opposing screens and really liked it. In the data, 58% liked the screen visibility while 28% did not. Students with less optimal visibility can move but tend not to.

The very simple design of the pod was well received and it is central to the functionality of the room. Happily, 86% agreed that the pods were "well designed for teamwork," and only 4% disagreed. Two different questions produced this result. A similar result was found for the value of including a visitor chair at the end of the pod. The students were evenly split on whether 2 computers per pod (4 students) were enough with 28% having neither sentiment. Many students bring laptops and having one per student would turn the room into a computer lab. On the other hand, three of the 8 classrooms in CEDE have no installed computers for student use at all. So a 50% computer density is quite functional and 63% are comfortable with it.

VII. DATA VARIABILITY

The table below reports how the three groups of responses varied in response to the prompt "Overall, I really like 316H." The first row has the data for Devon's class where students were subjected to much praise for the room. The second row has the data for students in the one faculty member who raised the most criticisms of 316H. The last row has data from the survey using the class email lists. The far right column shows the sum of agree and strongly agree values for liking the room. Apparently Devon oversold the room and his students came out the least positive, but not by much. So, while the survey was not random, these data indicate that there is not a lot of data variability and the results are believable. And, of course, the dislike values are very low for all three groups and about 6% overall.

Table I: N Cell Counts Liking Room 316H
1=Strongly Disagree; 5=Strongly Agree

	1	2	3	4	5	% (4+5)
Pos. Bias	0	1	9	10	5	60%
Neg. Bias	1	0	5	15	4	76%
No Bias	0	3	6	14	9	72%

VIII. CONCLUSIONS

The student team produced a design that has resonated well with the users, and which is also very compatible with the current literature on designing learning environments.

The flexible design is very important. It allows faculty to teach as they always have without any training. Conversely, it allows progressive faculty to use new methods and to change environments for particular assignments. The room should prove adaptable to future changes, as yet unknown.

Future research will include studying both the design team members to see what lasting impacts the experience has had on them. A perennial complaint of higher education is the lack of responsible, meaningful experiences that are available to students. Added to which is the apparent inability of most universities to include the student voice in the governance and running of the university. We allowed students to design a classroom and found that flipping this process was not just OK, but a good idea. They were highly motivated and very jealous of their autonomy.

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Integrating RFID Technology into a Course in Mechatronics

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***Abstract*—This paper proposes strategies and hardware for exposing students to radio frequency identification (RFID) technology in an introductory course to mechatronics. In the current course project, students are tasked with programming mobile robots to navigate a predefined route in an arena while avoiding collisions with one another and obeying traffic light signals. To do this, the robots are equipped with range sensors for navigation and a camera for identifying traffic lights in the arena. It is desired to introduce RFID to students as this technology has been gaining momentum in its applications in recent years. Three possible strategies for adding RFID to the current course project are proposed: RFID for sorting, RFID for localization and RFID for traffic management. It is found that RFID for traffic management is the best way to expose students to this technology in terms of working within the current hardware constraints and maintaining an appropriate level of difficulty for the students. Two cost-effective RFID readers are also tested to determine which is most viable for the implementation. It is found that a high frequency (HF) 13.56 MHz reader and a HF card-type tag provide the best read range and read speeds for the RFID-based traffic management project.**

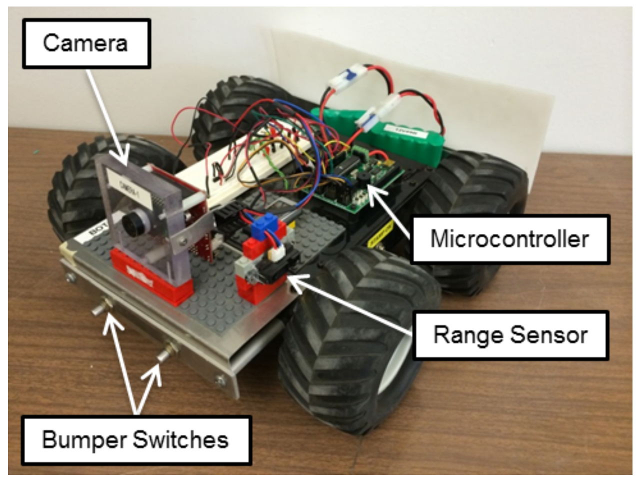

Fig. 1. Mobile robot hardware used in the current mechatronics course

I. Introduction

Radio frequency identification (RFID) technology has gained popularity in a wide array of applications due to reduced costs of manufacturing RFID tags [1]. Many applications are in manufacturing and logistics, where RFID is proposed as an alternative to barcodes for product identification throughout the supply chain. There has been rapid growth in this area of wireless mechatronic devices in recent years [2]; therefore, it is desired to expose students to RFID technology in an existing introductory course to mechatronics at the Department of Mechanical and Materials Engineering at Queen's University [3]. The course it taken primarily by 4th-year mechanical engineering students. There is no mechatronics option in the current mechanical engineering program, so for many students, this is their first exposure to microcontrollers and integrated systems. The course is taught in a studio-laboratory setting, where students get plenty of hands-on experience at programming microcontrollers and interfacing sensors.

The course provides an appropriate level of difficulty for many students to learn basic mechatronics concepts within the given time constraints. It is important that the introduction of RFID does not substantially increase the difficulty level of the course. There are three possible methods of integrating RFID to the current course project: sorting, localization or traffic management for mobile robots. Each method provides a realistic application of RFID technology, which gives some context for students to solve a real-world problem in the course project; however, each method must be carefully analyzed to ensure that the project remains at an appropriate level of difficulty. Furthermore, commercially available RFID hardware that are compatible with the Arduino microcontroller must be found and tested to ensure that they are viable for implementing any method.

II. Overview of the Current Course

The mechatronics course runs for 12 weeks with 2 hours of lecture and 5 hours of lab time per week. During the first 6 weeks, students are introduced to microcontroller programming and interfacing various sensors through a series of desktop and mobile robot labs. The labs are conducted in groups of two students. Weeks 7 through 11 are dedicated to the project period where students apply what they have learned in the labs to program a mobile robot that can navigate an arena that mimics a city street-scape. Groups of four students are tasked with programming two mobile robots to navigate

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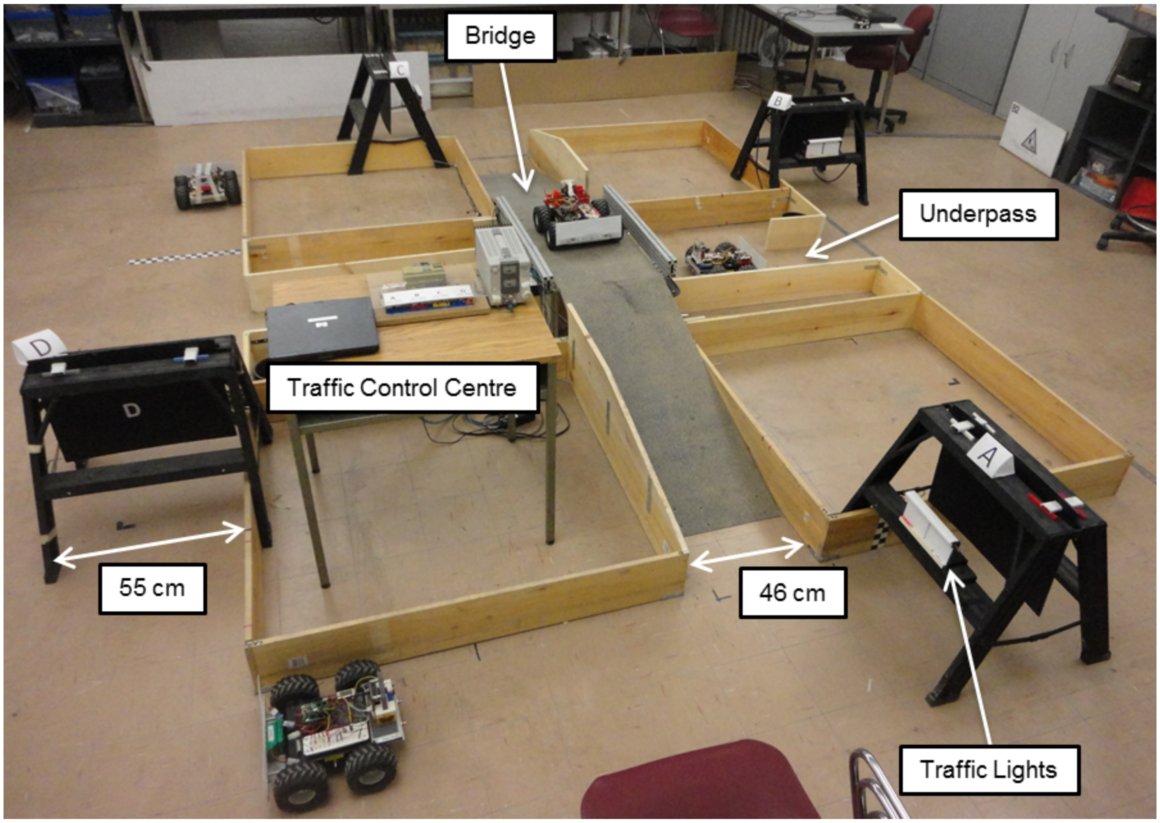

Fig. 2. Current test arena for the mechatronics course project

predetermined routes while obeying traffic lights and avoiding collisions.

A. Mobile Robot and Hardware

The mobile robot hardware and sensors used in the course are shown in Figure 1. The robot is a Lynxmotion A4WD1 v2 rover with a four-wheel differential drive system and deep-treaded tires. The chassis contains a front bumper with limit switches and rear bumper with battery holder. An Arduino microcontroller is used to control the robot. Range sensors and a camera are used as sensors for navigation. There is minimal mechanical design in this course as many of the students already have this experience through other courses in mechanical engineering. The focus is on learning to program the microcontroller and interfacing with the sensors to autonomously navigate the robot.

Students are allowed up to equip their mobile robots with up to three analog infrared range sensors and one camera. Most students use a left-facing range sensor for navigating the arena using a 'wall-following' algorithm. In the algorithm, the robot's distance from the walls of the arena is continuously measured as the robot moves forward. The differential wheel speeds are adjusted as required to maintain a certain distance from the wall. Corners are detected when there is a sudden drop in the measured value. The camera is used to identify traffic lights in the arena. Students first calibrate the RGB pixel values for a red light and a green light. During navigation, the pixels from the camera's field of view are processed to determine the number of pixels that are within a certain threshold for each coloured light.

B. Arena

The arena for the final project consists of a four-block roadway with a bridge, an underpass and four sets of traffic lights as shown in Figure 2. A 55 cm wide one-way road runs the perimeter of the four blocks; traffic must move in a counterclockwise direction. The bridge and the underpass allow two-way traffic, but only a single mobile robot can move through either at a given time. The widths of both the bridge and the underpass are 46 cm. Four sets of red and green lights control the traffic within the arena. A red light indicates that the robot must stop, a green light indicates that the robot must turn left (onto bridge or tunnel), no lights indicate that the robot must continue straight through. The lights are manually controlled from the Traffic Control Centre by a member of each team.

III. Integrating RFID Technology to the Course

RFID is a technology that enables the automatic identification of objects at a distance without requiring a line-of-sight. There are three components of a basic RFID system: reader, tag and middleware. A *reader* is used to interrogate a *tag* in order to obtain the tag's stored ID. *Middleware* is then used to process the tag data and do something useful with that information. The tags are typically *passive* meaning that they do not contain a power source; electromagnetic or radio wave energy transmitted by the reader is harnessed by the tag during interrogation. This energy is then used to transmit back the stored ID [4]. The technology is available in many forms and has many applications. Low-frequency RFID can be used for smart card applications such as keyless entry, while high-frequency RFID can be used for faster automatic identification applications such as electronic toll systems.

One of the most beneficial implementations of RFID technology is for the identification of goods in the supply chain. Replacing barcode labels with RFID tags provides a much greater efficiency for product identification tasks throughout the supply chain [5]. Another group technologies that have proven to be beneficial in the supply chain are automated guided vehicles (AGVs). These are robotic lift trucks and pallet movers designed for automated material handling tasks within a facility [6]. They typically navigate within the facility by following a marked *fixed path* on the floor, or *free ranging* by using laser triangulation. If the mobile robots in the mechatronics course are thought of as AGVs, then the arena can be set up as a mock-warehouse. RFID technology can then be used to solve common problems of sorting, localization, or traffic management [7]. The following subsections describe each of these methods and how they could be implemented in the course.

A. RFID for Sorting

Sorting involves equipping a mobile robot with an RFID reader and a gripper. The robot would be tasked with picking up RFID-tagged items at a loading zone and navigating to the correct location in the arena to put away that item. Such implementations have been tested by Chuan [8] and Fernando [9]. In both tests, the navigation route for each type of item needed to be pre-programmed into the robot's controller. This can be a tedious task, depending on the number of items to be sorted. If the robots are able to localize themselves within the arena, then there would be no need to program each route.

B. RFID for Localization

Localization can be accomplished by mounting an RFID reader to the under side of a robot and placing tags scattered throughout the arena floor. Many examples of RFID based localization methods can be found in literature [e.g. 10 to 12]. If implemented in the current course, the students would be required to program their robot so that it is able to start at any location in the arena and find it's way back to a 'home' location. Development of a localization algorithm would be the greatest challenge for students, and result in a project that is focused heavily on software and programming.

C. RFID for Traffic Management

Traffic management involves automating the traffic control in the existing arena using RFID readers and tagged robots. In this implementation, RFID readers would be placed throughout the arena, and the tags would be placed on the robot. As the robots move past a reader, the identity and location of each robot in the arena can be identified and the traffic lights can be changed accordingly. For this project, the RFID readers would be connected to a central controller which would also be connected to each set of traffic lights. The students would only be required to equip their robots with RFID tags and ensure that they get consistently read by all readers. This method would introduce the least amount of complexity to the current course.

IV. RFID Hardware Selection

Before RFID technology is integrated into the mechatronics course, it was important to find and test RFID readers that were compatible with the Arduino microcontrollers used in the course. Two such readers were found: a low frequency (125 kHz) reader and a high frequency (13.56 MHz). For each reader, the read range and read speed for different types of tags were tested. The model numbers for the tested readers and tags are presented in Table I. The results are summarized in the following subsections.

A. Read Range Test

The vertical and lateral read ranges of both readers were tested. This was done by first placing the reader at a fixed location. Next, a tag was moved toward the reader until it was detected by the reader. Then the distance from the centre of the reader to the centre of the tag was recorded. The tests were done for both readers using different types of tags: a card and a disc. For varying heights, the tag was moved towards the reader from multiple directions and the lateral ranges were averaged. Figure 3 shows the radius of the read range for each type of tag for increasing distance from the reader to the tag. It can be seen that for all cases, the horizontal reading range gets narrower as the vertical distance between he reader and the tag increases. The best vertical reading range was achieved for the HF card which was able to read tags from approximately 10 cm away. The HF card and LF card had the widest lateral read range radius at approximately 4 cm from the readers.

B. Read Speed Test

Read speed is generally not important for sorting, but for localization and traffic management the tags must be read while the mobile robot is in motion. As the card-type tags had the best read range, only the LF card and HF card were tested. To conduct the test, the tags were mounted on the mobile robot

TABLE I
SUMMARY OF HARDWARE USED FOR THE MOBILE ROBOT.

Item	Manufacturer	Model No.
HF Reader	Adafruit	PN532
HF Card	MiFare	Classic 1K Card
HF Disc	MiFare	Classic 1K "Laundry Tag"
LF Reader	Parallax	28140
LF Card	Parallax	28141
LF Disc	Parallax	28448

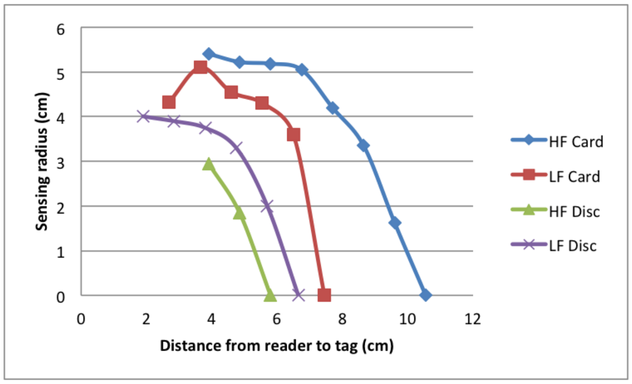

Fig. 3. Read range radius of different LF and HF tags for increasing distance between the reader and the tag.

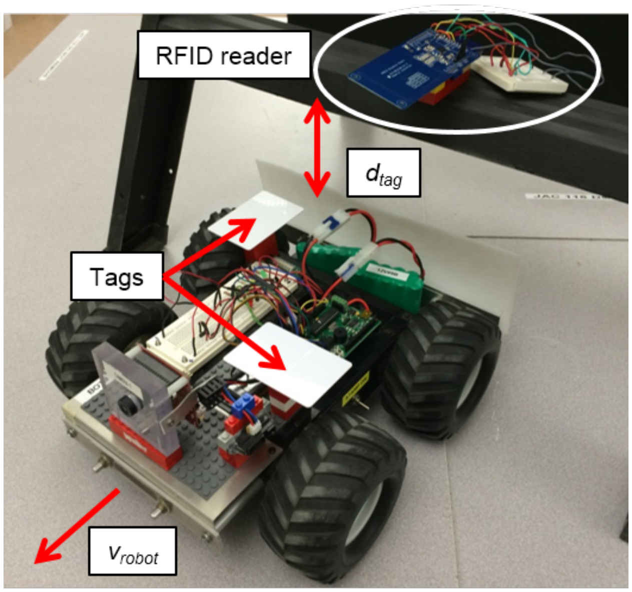

Fig. 4. Setup for testing the read speed of each RFID reader.

and the robot was driven at its maximum velocity v_{robot} = 1.2 m/s for varying vertical distance, d_{tag} between the tag and the reader as shown in Figure 4. It was found that at the robot's maximum, only the high frequency reader is able to read the tag. The HF reader was able to consistently read the HF card-type at distance, d_{tag}, upwards of 5 cm. The LF reader was not able to read LF card-type tag at robot's maximum velocity at all. Therefore, the HF reader is chosen as the best RFID hardware for the mechatronics course.

V. Conclusions and Future Work

Strategies and hardware for exposing students to radio frequency identification (RFID) technology in an introductory course to mechatronics were presented. Three methods of integrating RFID into the current course were proposed: RFID for sorting, RFID for localization and RFID for traffic management. It is found that RFID for traffic management is the best way to expose students to this technology in terms of working within the current hardware constraints and maintaining an appropriate level of difficulty for the students. In this case, the instructor would implement multiple RFID readers on the arena and program them to locate and identify robots and automatically control the traffic lights. The students will only be required to determine the optimal placement of RFID tags on their robot so that the robots are detected each time they pass underneath a reader. Two RFID readers which were compatible with the Arduino microcontroller were also tested to determine their viability in the proposed methods. Testing showed that the high frequency (HF) reader and HF card type of tag are the most viable for this application. The HF reader was able to detect tagged robots as they travelled at their maximum speed of 1.25 m/s with the tag placed at 5 cm below the reader.

The automated RFID-based traffic management system for the arena is currently being developed. The set-up will involve connecting four RFID readers, scattered throughout the arena, to a central computer for robot identification, and a microcontroller to automate the traffic lights. The computer and microcontroller will communicate with each other through serial data communication. Finally, one of the existing laboratories will be modified to introduce RFID to students.

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Creating Future Engineering Researchers Beginning at Undergraduate Level

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***Abstract* - Research Experiences for Undergraduates (REU) Sites in *Sustainable Urban Environments* was offered from 2011 to 2013 at University of Cincinnati (UC) in the U.S. The program was funded by the U.S. National Science Foundation (NSF) with a primary goal of introducing undergraduate engineering students to research and encourage them to pursue careers in research. This paper presents how the whole research program is planned and conducted, the research training provided, procedures used to evaluate the impact of the program, process used to track the students, and the outcomes of the programs. It is believed that this paper will benefit others in planning and executing a similar program at their institutions.**

Each year nine to ten undergraduate students from different engineering disciplines are recruited to conduct research in engineering for eight weeks in summer. An effort is made to fill at least 33% of the positions with underrepresented students. Students are given a stipend, board and lodging expenses, and travel costs. Priority is particularly given to students from primarily undergraduate programs where no research opportunity are available. Students are divided into 2-3 teams and worked on four different projects focusing on *Sustainable Urban Environments* under the close guidance of a faculty mentor and a graduate research assistant. Training programs are offered to enhance students' skill in engineering research process, critical thinking, and research tools needed.

By the end of the program, each team submitted Technical Paper, PowerPoint Presentation, and Poster, which were judged by an invited panel of external judges. The judges fill out a scoring form evaluating the contents and qualities of the deliverables. Students are asked to complete program satisfaction and attitude surveys probing students' perceptions about research as a potential career option and the role or research in improving quality of life.

From the judges' evaluations and student surveys conducted, some of the major successes of the program include changes in attitudes and opinions about graduate school and research, increased enrollment in graduate school, and submission of research papers to student paper presentation competitions and peer-reviewed conferences and journals. It is expected that perception of research will become more positive as students conduct research activities, view themselves as successful participants in larger project, and build mentoring relationships with graduate students and faculty members.

Keywords: *Undergraduate Research, Engineering, Graduate School*

I. INTRODUCTION

Our engineering schools now face internal and external challenges, impacting the marketability of our students. With improved telecommunications and digitization, more engineering can be done without close proximity [1]. However, off-shoring is likely to have little impact on the most highly educated engineers. Thus, engineering education is evolving, with more emphasis on graduate education, as outlined in a recently released series of reports by the NAE [2, 3]. Educators recognize that undergraduate research motivates students to apply for graduate school, and underrepresented groups must become an integral part of such a technical workforce. The Boyer's Commission [4] asserted that research universities often miss opportunities to enrich and strengthen undergraduate education by providing exposure to faculty research and the research process. Recent statistics indicate that a declining population of engineers is pursuing advanced degrees [5]. REU programs are widely promoted as an effective educational tool for enhancing the undergraduate experience [6, 7] with multiple benefits [8], the most instrumental of which is an increased interest in STEM careers [9, 10]. REU fosters increased persistence in the pursuit of an undergraduate degree [11]; increased interest in pursuing graduate education [12, 13]. REUs help develop career pathways for underrepresented students by increasing minority retention [11] and the number of minority students pursuing graduate degrees [14].

Other disconcerting trends are emerging: 1) The M.S. engineering enrollment peaked in 2005, and has decreased by 3.9% in 2008 [15]. 2) Even though women make up 56% of the undergraduate college population [16], only 17.9% are engineering undergraduate students. 3) The share of African-American and Hispanic students has remained low and virtually unchanged for the past decade. Despite comprising 25% of the U.S. population, these two groups at the M.S. level just earn, respectively, 4.6% and 5.5% of the degrees [160]. Doctoral representation was lower for each population with African-Americans receiving 3.6% and Hispanic students receiving 3.5% of the degrees [15]. 4) In 2007-08 more than 58.3% of all U.S. engineering doctoral degrees were awarded to foreign nationals [15]. U.S. security concerns are reducing the number of foreign students, while competition from other countries and opportunities to return to their home countries are increasing. For decades, other countries have strengthened their investment in science and engineering higher education. If current trends continue in the next decade, more than 90% of all scientists and engineers in the world will be living in Asia [17]. The percentage of foreign doctoral recipients who stay in the U.S. may return to the lower 50% level that existed until 1992.

The REU site on *Sustainable Urban Environments* (SUE) was executed at University of Cincinnati during summer of 2011, 2012 and 2013 with a main goal of providing an 8-week summer full-time in-residence research training and seminars and workshops on the use of modern technology in conducting and disseminating cross-disciplinary research. Four main research areas are selected based on four of the grand challenges that impact sustainability of urban environments in an interdependent way. The projects are: 1) Access to Clean Water. In this project students study water treatment technologies that are becoming increasingly important in the need for water reuse, contribute to developing strategies for optimal application of these technologies in the field. 2) Renewable Energy Sources. In this project, students investigate fundamental advances in nanotechnology and apply to the optimization of solar and proton exchange membrane fuel cell design. 3) Carbon-Sequestration Methods. This project aims to demonstrate the capability of microalgae to sequester CO_2 and uptake nitrogen from waste water. 4) Improved Urban Infrastructure. This project aims to investigate the contribution of traffic to air pollution using modern sensor technology. The main objective of the REU program is to encourage talented undergraduates to enroll in graduate school by exposing them to research.

II. PROGRAM STRUCTURE AND ACTIVITIES

The basic approach to the research is discovery through actual construction, experimental testing and/or computer simulation, observing and recording, synthesizing the data collected, and generalizations. This approach provides an opportunity for individual growth and challenge to the young and inquisitive mind. Three students work as a team on one research thematic project for 8 weeks during the summer, specifically carved out for the REU from ongoing research of a research Area Coordinator (AC)-a faculty member. The AC and a Graduate Research Assistant (GRA), usually a doctoral student, guide research of the team on daily basis. In each team, one student acts as the team leader on a weekly rotating basis, and is responsible for reflecting on the daily activities in a log book. Additionally, each Friday each AC, GRA and REU participant complete an online Weekly Progress Report Survey Form, which has questions seeking information for number of weekly meetings held, aggregate progress made towards overall goals, and strategies implemented to enhance productivity. Results are tabulated and shared with all constituents at the start of the following week to ensure transparency. Every alternate day at 8:00 am the AC and the GRA for each research project hold a meeting with their students in which the team leader presents the work planned and any problems encountered. Students are trained to conduct the research through a combination of seminars and half-day workshops including: 1) Research content training seminars by AC and GRAs; 2) Research skills training workshops including Online Literature Search, Public Speaking and Communications, Project Documentation, Statistical & Uncertainty Analysis and Poster Making; and 3) Enrichment training seminars which include Ethics in Engineering Research, Taking Research from Lab to Real-World--Intellectual Property & Patent Issues, and Graduate Education Opportunities and Application Process. Additionally at least one field trip connected with each REU thematic research projects is carried out and students are asked to write a written report following the trips.

Students participate in mentored longitudinal writing assignments, oral presentations, and a juried final Poster, PowerPoint, and Technical Paper presentation competition. After the REU program, the AC and GRA will help students to condense their technical paper for publishing and presentation in conferences, journals, or student paper competitions (at least one). Funds from the project are used for them to travel to these meetings. After returning to their home institution, each REU participant is required to make at least one presentation.

To prepare the students for the research, reading material are sent 4 weeks prior to their arrival. It includes: project goal and objectives, important literature, tentative study plan, descriptions of test procedures and equipment, weekly activities, and information about team partners. On the first day of the project, discussions are made with the teams on the nature and scope of their project, expectations, deliverables, and introduce general lab safety rules, the lab facilities and ongoing research projects, and other graduate students and faculty. Students research the pertinent literature given to them and additional available literature. Weeks 2-7 are primarily devoted to research skills training workshops, seminars, and conducting the research and presenting interim progress reports. Every alternate Friday afternoon each team will submit a biweekly written report and give an oral PowerPoint presentation in which each student participates. This approach promotes team work, and provides an opportunity to each student to lead the discussion. When the projects are nearing completion, using the biweekly reports, each student team writes a technical paper and prepares a display poster. Each team give a final 1/2-hour PowerPoint presentation, which along with the technical paper and poster will be judged by an invited panel of judges. The judges select the “Best Project” considering both the report and presentations.

III. OUTCOMES OF THE PROGRAM

A. Number of Students Participated

A total 30 students have participated: 11, 10 and 9, respectively, during summer of 2011, 2012, and 2013. The gender distribution consisted of 11 men (36.7%) and 19 Women (63.3%). The men consisted of 9 white men (30%) and 2 minority men (6.7%). The women consisted of 7 minority (23.3%) and 12 white women (40%). Total ethnicity distribution is 20 white (66.7%) and 10 minorities (33.3%). A total of 21 (70%) underrepresented participants have been selected – goal was 33%. The students are from 16 different institutions among which 11 (68.8%) are PhD granting.

B. Judges Evaluation of Presentations

A direct measure of the effectiveness of the program is obtained from a panel of externally invited judges. Each year the students produced three deliverables (Technical Paper, Poster and PowerPoint Presentation) and the judges evaluated each deliverable on a 4-point scale (4 = Excellent, 3 = Very Good, 2 = Good and 1 = Fair) in the following general categories: Content, Organization, Clarity, Quality, and Presentation. Detailed judge scores for Technical Paper, Poster, and PowerPoint Presentation are presented in Table 1 below. The composite average score of the scores given by the judges for the REU team Technical Paper, Poster and PowerPoint Presentation are 3.12, 3.50, and 3.49, respectively. The overall average judges' score for the 3 years is 3.37/4.00, which is between very good and excellent.

Table 1: Summary for Judge Evaluations for Technical Paper, Poster and PowerPoint Presentation

Technical Paper						
Year	Content	Organization	Clarity	Technical Merit/Grammar	Visual Appeal	Average
2013	3.38	3.44	3.38	3.19	3.13	3.30
2012	2.94	2.56	2.75	2.81	2.44	2.70
2011	3.69	3.38	3.31	3.25	3.13	3.35
Average	**3.33**	**3.13**	**3.15**	**3.08**	**2.90**	**3.12**
Poster						
Year	Content	Organization	Clarity	Visual Aids	Presence	Average
2013	3.81	3.38	3.50	3.75	3.63	3.61
2012	3.50	3.19	3.31	3.19	3.63	3.36
2011	3.81	3.50	3.38	3.19	3.75	3.53
Average	**3.71**	**3.35**	**3.40**	**3.38**	**3.67**	**3.50**
PowerPoint Presentation						
2013	3.56	3.69	3.56	3.50	3.44	3.55
2012	3.25	3.56	3.44	3.06	3.25	3.31
2011	3.69	3.75	3.69	3.31	3.63	3.61
Average	**3.50**	**3.67**	**3.56**	**3.29**	**3.44**	**3.49**

C. Post-REU Satisfaction Survey Results

To assess the success of the different programs, experiences, and activities executed in the REU Site the students are asked to complete a Project Satisfaction Survey Questionnaire on the last day of the program.

The main strength of the REU project as reported by the participants is that they obtained a valuable research experience which many undergraduate students do not have the opportunity to participate. Many of the students stated that working with the faculty mentor and the graduate student mentor as a team was a very beneficial experience. Their interaction with the graduate students gave them an idea of the benefits of graduate school and all REU participants are highly satisfied with their graduate student mentor.

The participants also stated that they obtained first-hand experience conducting and reporting research in graduate school. Some participants are appreciative that they are able to gain this understanding early in their undergraduate educational career. They are able to apply problem solving abilities and to think critically about the experimental and analytical problems connected in their research. They are also able to better formulate their own research questions, identify the research tasks to answer them, and establish a time-line to execute them. They understood that this is a dynamic process and the timeline has to be adjusted as the research progresses. They understood how to progressively complete the research and the production of the deliverables simultaneously (technical paper, poster and PowerPoint presentation). Almost all participants indicated that their technical writing and oral presentation skills improved significantly due to participation in the REU project. Additionally, the structure of the REU program provided upfront training on research content, laboratory safety, and use of specialized research equipment, which provided them all of the necessary tools to complete a research project. The students also completed literature reviews before beginning their projects, developing skills in literature searches, reading and writing technical papers. This is planned throughout the 8 week session with Bi-Weekly presentations of progress through the research projects.

An additional strength of the REU project according to the participants is that the program imbibed the confidence in them to understand the research in a specialized area, especially in the application of the research. They are also excited about the challenge of acquiring new technical knowledge. The students reported that they gained the knowledge and expertise needed to complete the research and produce, present and defend high quality research deliverables.

D. Results of Tracking Surveys

An online Tracking Form requesting every participant to fill their educational progress, plans for graduate school, REU's impact on them, and list of any presentations and publications they made is developed. All past REU students are asked to fill the Tracking Form every year up to 5 years. It is found that a total of 29 publications (i.e., conference papers, poster presentations and journal papers) resulted from SUE REU Site participants. Among these 20 of them are jointly authored by the students and faculty mentors and 3 of them are journal publications. One student won a paper award. It is found that twenty (66.7%) of the students are still attending undergraduate degree and 10 (33.3%) of them have graduated. Out of the 10 students who graduated, 9 (90%) of them have joined graduate school.

IV. CONCLUSION

It can be concluded that the REU program gives the students an experience on how to organize and conduct a research project with defined goals and objectives thereby enhancing their interest in graduate school. The students are able to acquire team work and collaborative learning skills (between participant and participant, participant and graduate student mentor, and participant and faculty mentor) that are the major elements of graduate education. Students' attitude about research has changed and their self-confidence to explore new ideas has improved. It is found that exposing students to research beginning at early levels of undergraduate will increase their interest in research and encourage them to join graduate school.

ACKNOWLEDGMENT

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Scholars of Excellence in Engineering and Computer Science Program, an NSF S-STEM Grant: Assessment and Lessons Learned – First Award

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Abstract—**The Scholars of Excellence in Engineering and Computer Science (SEECS) program initiated its first cohort of 20 students in fall 2009. Funded through a National Science Foundation (NSF) S-STEM grant, the interdisciplinary, multi-year, mixed academic-level program offers scholarships to students based on academic merit and financial need. The first grant ended in June 2013 and a second grant was awarded to continue the program. The innovative and engaging aspect of the SEECS program is a zero-credit seminar where students are required to attend specific development sessions and learning outcomes are realized in a team-based, project-based approach. The SEECS seminar encompasses three components: engineering design, professional development, and personal development. The engineering design component is the pivotal experience connecting and building not only engineering competency but also personal confidence. Each academic level has different professional and personal development objectives realized each semester. In an attempt to measure the effectiveness of the program and to provide performance indicators to identify early in the student's college career a potential, at-risk student, the authors have analyzed additional elements beyond the reports required by the NSF. First, data is presented correlating high school SAT, ACT, and GPA with scholars' retention within the program. Second, retention data of the scholars is shown as a measure of the program's success when compared to the retention values for School of Engineering and Computer Science and for the university. Finally, the paper presents the lessons learned during the development, implementation, and assessment of the SEECS program.**

Keywords— assessment, innovative practice;

I. Introduction

The National Science Foundation (NSF) Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM) Program, established in compliance with the American Competitiveness and Workforce Improvement Act of 1998, provides scholarship funds for students in STEM fields who demonstrate academic talent and financial need. The goals of the S-STEM program are to be supported by institutions receiving the awards and are outlined as [1]:

- Improved educational opportunities for students;
- Increased retention of students to degree achievement;
- Improved student support programs at institutions of higher education; and
- Increased numbers of well-educated and skilled employees in technical areas of national need.

To-date, Gannon University has received two consecutive NSF S-STEM grants, Nos. 0806735 and 1153250. The first award (2008-2013), the one assessed in this article, consisted of one year dedicated to logistics and four years of students' scholarships. With these funds, the Scholars of Excellence in Engineering and Computer Science (SEECS) program was established in order to achieve the following goals:

1. Increase the number of academically talented, financially disadvantaged students enrolled in Gannon University's computer science and engineering programs, especially minority, female, and disabled students.
2. Through a program of scholarships and rigorous academic support, assist students to continue their education through graduation.
3. Foster professional development that prepares students for careers in STEM fields and graduate education.

The SEECS program structure and activities were designed, implemented and formatively evaluated to achieve four objectives:

- **Objective 1:** Provide 20 scholarships per year for academically talented, financially disadvantaged STEM majors, especially those from underrepresented groups.
- **Objective 2:** Build a referral network arrangement between Gannon University, the Erie City School District, and the local U.S. Department of Education Talent Search program to identify and recruit financially disadvantaged students from underrepresented groups who meet SEECS scholarship eligibility requirements.
- **Objective 3:** Provide a program of academic and student service support that achieves a 90% year-to-year retention rate for SEECS scholars.

- **Objective 4:** Provide scholars with academic and professional development that prepares them for graduate school and/or employment in a STEM field.

The innovative and challenging aspect of the SEECS program is the Professional and Personal Development Seminars through which Objectives 1, 3 and 4 are realized. This required zero-credit, pass-fail course offers a single, shared experience for all scholars addressing different professional and personal needs of each academic class (i.e., freshman through senior). The SEECS seminar encompasses three components: engineering design, professional development, and personal development. Through workshops, university support services, lectures, and invited speakers, the facets of professional and personal development are addressed [2]. Scholarships are renewed year-to-year for those students who maintain a minimum 3.0 cumulative GPA, demonstrate financial need as per FAFSA, and comply with seminar attendance requirements. A formative evaluation suggested enhancements to the program's activities.

II. The Current Student Profile

The grant stipulates awarding requirements for high school students and renewal criteria. The potential scholars must declare one of the qualifying majors in the School of Engineering and Computer Science (ECS). In addition, high school students must achieve a minimum score of 1100 on the SAT (math and verbal) or a score of 24 on the ACT, and a minimum high school GPA of 3.0 (on a 4.0 scale) for consideration of scholarship receipt.

For each prospective scholar, the selection committee is provided the intended major, the SAT/ACT score(s), name and city of high school, and high school GPA. When provided, rank in class is also considered. The committee weighs potential as measured by SAT/ACT and achievement as measured by high school GPA. In reviewing high school data from the first four freshman classes entering the SEECS program, some interesting trends appear.

Data for Fig. 1 and Fig. 2 includes only scholars who either 1) are still in the program or graduated as members of the program, or 2) left the program because of low academic performance or transferred major with relatively weak academic performance. The values for Fig. 1 are based on either the students' SAT or ACT score mapped to the equivalent SAT score. If the student provided scores for each, the higher score is used. Fig. 1 indicates that SAT/ACT scores do not have strong predictive value for success in the SEECS program. Scholars leaving the program are dispersed throughout the range of SAT/ACT scores. While helpful as a factor in predicting future success, SAT/ACT scores by themselves cannot be the selection criteria.

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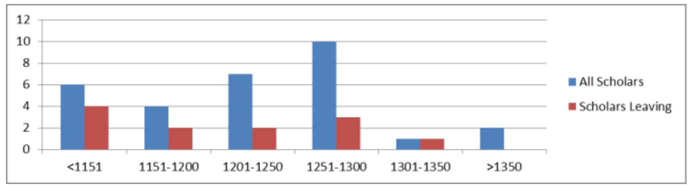

Fig. 1. Scholar Performance Based on SAT/ACT

The values for Fig. 2 are based on the reported high school GPA for each student, without adjustment. Consequently several GPA values are above 4.0. This figure indicates that GPA seems to be a stronger predictor of success in the SEECS program than does SAT/ACT. Many scholars with high school GPA of 3.9 or below were unable to maintain a college GPA above 3.0 through graduation, while only one of 15 scholars with high school GPA above 3.9 was unable to maintain the required 3.0 GPA in college.

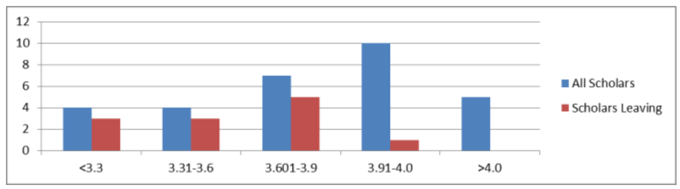

Fig. 2. Scholar Performance Based on High School GPA

III. The Current SEECS Scholar Compared to Peers

The average SEECS scholar is an academically-superior student among many academically-strong students. To investigate how SEECS students compare to their non-SEECS classmates, retention measures are used. Retention is a standard measure reported by universities to various external reviewing agencies such as to accreditation boards (for instance, ABET) or to the Common Data Set (CDS) Initiative [3]. Universities tend to report retention relative to defined cohorts continuing from year to year, offering a freshmen retention rate, a sophomore retention rate, and so on.

Freshman year is a hallmark year in the academic development of a student within an initial major. Modifying the environment and the interactions available to students within the year has been recommended by studies [4, 5]. Honken and Ralston report (1) "…students expect to communicate with faculty outside of class" and (2) "…encourage group studying by designing a variety of assignments to be completed with other students," [5, p. 34]. Similar recommendations had been made in 2007: "…an interdisciplinary first-year projects course should be required in all engineering programs," [4, p. 10]. Involving students in small-group projects with high faculty collaboration is repeatedly valued as a factor for improving student retention in engineering and the sciences. The projects do not need to be within the student's primary discipline; communication and dialogue, sharing of ideas and approaches are more important.

The SEECS Scholarship program is styled to incorporate all of these recommendations. Table I shows a comparison of the retention rates for SEECS scholars compared to their university peers, relative to the years of the first grant, 2008 through 2012. The percentages describe retention for the SEECS program. Retention in the program is defined within the grant as scholars who fit the following stipulations: (1) remain in STEM majors, maintain academic qualification, and continue with financial need, (2) remain in STEM majors with qualifying grades, but have lost financial need, or (3) remain in STEM majors, but not ones funded by the grant. The other circumstances of leaving the university entirely, dropping below academic qualification specified in program, or leaving STEM majors, but remaining in the university are considered to be "not retained." Row 1 identifies students who entered the SEECS program as freshmen and qualified as being retained by the previously stated clause. Row 2 identifies SEECS freshmen who remained at the university either in a STEM major or another.

Comparison of Row 1 to Row 3 show the retention of SEECS freshmen did not exceed freshmen retention rates with the School of Engineering and Computer Science (ECS). Comparison of Row 2 to Row 4 shows the tendency of SEECS students, who had become familiar with the university, had remained within the university community more so than the general university freshmen. Certain anecdotal factors about the pool of SEECS freshmen can be said: (1) in any one year the size of the pool ranged from 14% to 18% of the entire ECS freshmen class, (2) the pool is not a random sample across a spectrum of abilities, and (3) students can remain in ECS with a cumulative grade point average of 2.0 while students in SEECS must maintain a 3.0 to continue in the program.

Table II shows SEECS scholars are also successful in their post-baccalaureate efforts: (1) in three of the four years, the percentage of SEECS majors employed in their field exceeded the ECS percentage; (2) in all four years, the SEECS percentage exceeded the university levels of employment within major, and (3) overall 22% of the SEECS graduates eventually continued on to graduate studies while employed.

These comparisons indicate the persistence of SEECS students to complete their STEM studies and to be employed in their fields. The SEECS program enabled the students to identify in the first year a true interest in STEM majors. Those with the interest and the ability would ultimately graduate within the STEM major and the funded scholarship enabled the SEECS students to complete their studies.

IV. LESSONS LEARNED

As the SEECS program has developed, trends have been noted which can be used to guide future efforts.

High school GPA versus SAT as predictor: It has previously been demonstrated (Section II) that the method of selection of scholarship recipients should be reviewed in light of retention rates (Section III). A stronger correlation between high school GPA and retention is shown than between SAT score and retention. SEECS faculty members postulate that GPA is a measure of achievement, whereas SAT score is a measure of potential. It seems, within the limits of the SEECS experience, that achievement trumps potential. In the selection method used, GPA was implicitly downgraded in importance, owing to perceived non-uniformity of calculation due to honors courses and other bonus points. Possibly, the accumulation of such "bonuses" indicates character or ability which in turn indicates potential for successful retention.

Opportunities for enhanced retention: Analysis of retention rates of SEECS students in comparison to all students of the ECS shows SEECS retention is about the same. Objective 3 sought a 90% year-to-year retention rate. To be fair, renewal of a SEECS scholarship is not automatic upon continuance in an eligible major: SEECS students must also maintain a minimum 3.0 GPA; ECS has a minimum 2.0 GPA. However, in order to improve retention, SEECS faculty members have identified some specific courses, notably Physics and Calculus, which are troublesome. While the university provides on-demand tutoring for Calculus, no such on-demand tutoring for Physics is offered. Also, no mechanism within the SEECS program mandates students seek tutoring. Many students see such tutoring as stigmatizing, and therefore decline to accept it. Thus, the lesson is to provide and sometimes to mandate additional tutoring assistance for at-risk students. This approach might also provide additional opportunities to build collegiality and sense of community among SEECS students, as upper-level students can be enlisted to assist lower-level students in coursework. In effect, upper-level students may currently be an untapped or underutilized resource which can be put to effective use for building a stronger community.

STEM affinity predictors: SEECS retention rates as calculated penalize for major change to a non-STEM field. It is of course understood that students sometimes change major in college. Inasmuch as the goals of SEECS and the NSF S-STEM grant program are to recruit and retain students to graduation in a STEM field, major changes to non-STEM fields are problematic for grant objectives. It would thus be quite useful to have an idea of students' affinity for STEM, prior to acceptance into the SEECS program. A timely means of assessing true interest in the declared eligible major must be sought, to better ensure retention.

Targeting specific populations: The paper has not presented demographic data about SEECS scholarship recipients. However, in short, the SEECS cohort has not, through the period of the grant reported here, differed significantly from the demographics of the overall student population of ECS. The NSF grant has since been renewed with special emphasis placed upon recruitment of women and underrepresented minority students. To achieve this objective, special marketing materials have been made which go only to women students and hand-written notes are sent to identified students, chosen for their ability to assist in diversification of the SEECS student cohort. There is not sufficient data to-date to definitively state whether the new emphasis is paying off in terms of conversion, but early indicators are positive – the number of women applicants and the percentage of women applicants are both significantly up this year, relative to previous years.

ACKNOWLEDGMENT

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Table I. Retention Comparisons for Grant Years 2008-2013

	ENTERED Fall 2008 RETURNED FALL 2009	ENTERED Fall 2009 RETURNED FALL 2010	ENTERED Fall 2010 RETURNED FALL 2011	ENTERED Fall 2011 RETURNED FALL 2012	ENTERED Fall 2012 RETURNED FALL 2013
1. SEECS FRESHMEN Retained In School of Engineering and Computer Science		**75.00% (6 of 8 retained)**	**83.33% (5 of 6 retained)**	**70.00% (7 out of 10)**	**77.78% (7 of 9 retained)**
2. SEECS FRESHMEN Retained In University		**100% (8 of 8)**	**83.33% (5 of 6)**	**80% (8 out of 10)**	**88.89% (8 of 9 retained)**
3. Within the School of Engineering	93.75%	85.11%	83.33%	75.00%	82.81%
4. Within the University	81.57%	79.35%	79.48%	80.15%	79.09%

Table II. Graduation and Placement Comparisons

Graduated in Spring …	2010	2011	2012	2013
SEECS Scholars				
Graduates	**3**	**6**	**4**	**5**
Survey Respondents Employed within STEM field	**100.0% (2)**	**100.0% (6)**	**75.0% (3)**	**100.0% (5)**
Pursuing graduate studies, full-time	**0%**	**0%**	**0%**	**0%**
Pursuing graduate studies, part-time while employed	**66.7% (2)**	**0%**	**0%**	**40.0% (2)**
Employed in non-STEM field	**0%**	**0%**	**25.0% (1)**	**0%**
Unreported	**1**	**0**	**0**	**0**
Within the School of Engineering				
Responding Graduates	23	33	36	40
Employed within STEM field	69.6%	66.7%	83.3%	77.5%
Pursuing graduate studies	13.0%	15.2%	8.3%	20.0%
Unreported	7	5	3	6
Within the University				
Responding Graduates	455	420	435	472
Employed within major field	44.4%	44.4%	42.5%	42.4%
Pursuing graduate studies	43.3%	43.6%	43.9%	43.4%
Unreported	62	72	66	64

Work In Progress: Development and Evaluation of a Material Balance Concept Inventory

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***Abstract*—Material balance, is a mathematical representation of the big idea 'Conservation of Mass', which is used extensively in the field of environmental engineering. Although the concept is typically introduced in an introductory environmental engineering course, students are expected to continue to use and apply material balance concepts in their upper level classes. A conceptual understanding of this concept is essential for students to excel in other upper level courses, including those dealing with topics in water and wastewater treatment, solid waste management, water quality, and air pollution modeling. However, past experiences in classrooms have shown that students have difficulty in mastering these concepts due to alternate conceptions that they might carry to the classroom. It is important for instructors to know what previous knowledge or alternate conceptions students bring into the classroom to effectively address those before teaching new concepts.**

Concept inventories (CI) have been used effectively in in other fields to assess student understanding of concepts and to help improve teaching methods. Here we developed a concept inventory that will help in assessing student learning of core concepts in material balances and identifying the different alternate conceptions that prevent students from mastering these concepts. A Material Balance Concept Inventory (MBCI) was developed based on the results of a previous study. The MBCI was developed as an online multiple choice survey with provision for students to explain their thought process in arriving at the answer. This will allow us to find additional alternate conceptions. Students who have been previously exposed to mass balance concepts in environmental engineering at MSU were selected as survey participants to evaluate the inventory. We believe that this study will help to create a tool that can help in assessing student learning and eventually help in developing alternate teaching methods to teach these concepts effectively.

Keywords—Material Balance, Concept Inventory, Alternate Conceptions;

I. Introduction

Material balance is the mathematical model describing the big idea "Law of Conservation of Mass". It is a core concept in the field of environmental engineering. Students model a given problem based on the known/given values and the unknown that they are trying to determine. This core concept, which is analogous to an accounting system, is used across many areas of environmental engineering such as water and wastewater design, hydrology, and air pollution. Undergraduate students in environmental engineering programs across United States are introduced to this concept either in their sophomore or junior year and are expected to apply the concepts throughout various upper level classes and post-graduation. Sample environmental systems are presented to the students either as case studies or short problems. These environmental systems are typically modeled as simple ideal reactors and the reactions that occur in the system are modeled as first order kinetics. An understanding of the different types of reactors and the reaction kinetics that occur in these reactors is required to perform mass balance calculations. Students are also expected to make certain assumptions to simplify and model these systems as ideal reactors. However, our previous experiences in lower and upper level environmental engineering classrooms have shown that students have difficulty in understanding these concepts. In particular students time and again solve these problems by treating the models as mathematical equations into which they can simply "plug" in the parameters and "chug" to obtain an answer. In doing so, they often disregard and violate the assumptions underlying the models. They also seem to carry alternate ideas as to why the models should still fit the new assumptions. To effectively teach these concepts we have to understand and clarify these alternate conceptions. Hence there is a need to understand why students have these difficulties and how they think through these problems.

II. Background

Effectively designed concept inventories (CI) have been used as powerful formative assessment tools in other fields [1-5] to identify alternate conceptions among students. CI's are usually developed as multiple choice questions with the choices designed carefully to represent several alternate conceptions. Thus, to use the concept inventory effectively, it is very important to design the questions such that the 'wrong' answers represent only one concept. It is also equally important to validate the concept inventories to ensure that they test what the author seeks to be tested. As such, the development of concept inventories is an iterative process. In addition to help understand alternate conception, concept inventories can also be used to assess student learning and to develop alternate teaching methods [6]. However until now there are few concept inventories that have been developed and tested for assessing student learning of material balances. Two of these CIs were developed for material balances in the context of chemical engineering dealing with alternate conceptions with flow rate, etc. [7, 8]. A recent work in progress study published describes the development of a concept inventory for several environmental engineering concepts including material balances [9]. Here we present the preliminary results of a work in progress study for developing and evaluating a mass balance concept inventory (hereafter referred to as MBCI) in the context of environmental engineering. We believe that the concept inventory will help in assessing student learning in classrooms and in developing alternate teaching methods that will address the alternate conceptions.

III. Procedure

An overview of the procedure followed in this study is presented in this section and each step is described in detail in the sections that follow. The first step in the development of a concept inventory was to identify the different sub-concepts of mass balance with which students have difficulty. Once these sub-concepts were identified a concept inventory that tests each of these sub-concepts specifically with questions and distractors was developed. The concept inventory was internally validated before it was administered to students as an online survey by an environmental engineering professor and several graduate students. We have conducted a preliminary analysis of the results of the survey and are in the process of identifying other environmental professionals who could further validate the survey. The survey will also be refined in the future (iteratively) and will be used in the classrooms as pre- and post-assessment tools to assess student mastery of mass balance concepts. The preliminary results of the survey are also being used to identify alternate teaching methods that could be used in the classroom.

A. *Material Balance Concepts*

The results of a previous study conducted by the authors were used to identify the specific sub-concepts in material balance with which students had the most difficulty [10]. This study was conducted with 30 participants in an upper level environmental engineering course at Michigan State University. In this study student response(s) on material balance problems from exams, in-class group work, homework, and online formative assessments were analyzed. These problems were numerical problems requiring students to draw schematics and explain their approach in solving the mass balance problems. Based on the results the following sub-concepts were identified for use in the concept inventory – state of the system, ideal reactors and the assumptions underlying them, difference between the types of ideal reactors, reactor kinetics and the relationship between parameters such as detention time, flow rate and volume. The information obtained from this study was also used to develop the concept inventory questions and distractors.

This work was supported by a fellowship (Fellowship of Academic Scholars in Teaching (FAST) granted to the first author by The Graduate School at Michigan State University and the MSU Center for the Integration of Research Teaching and Learning (CIRTL) Steering committee.

B. *Study Population*

Participants for this study were recruited from the students who have previously enrolled in two upper level environmental engineering courses that deal with material balance concepts. Among the 79 unique students from this pool, 49 students were currently enrolled at Michigan State University. Ten out the 49 students participated in this survey and were compensated for their time. The distribution of the undergraduate majors of the participants is shown in Figure 1.

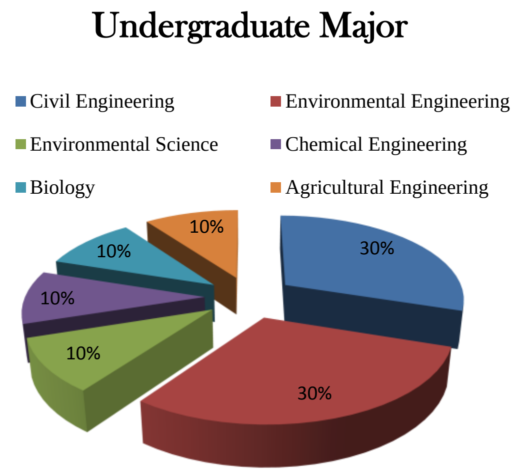

Figure. 1. Undergraduate majors that the survey participants belonged to.

C. *Concept Inventory*

While typical concept inventories in other fields are developed with only conceptual questions, in this study questions were designed as both conceptual and quantitative problems. Quantitative problems were included to ensure that the text choices did not provide hints and therefore skew the results of the study. Other previous material balance concept inventories also have used a similar approach by using numerical problems [7, 8]. The concept inventory was developed as an online survey using SurveyMonkey®. The survey was designed with nine metadata questions that collected the participants' background regarding material balance concepts. In addition to the metadata questions the survey consisted of 19 multiple choice conceptual and quantitative problems. Each problem was designed to test a specific concept. A sample problem from the concept inventory is shown in Figure 2.

The multiple choices were designed using distractors that represent a specific alternate conception. For example in the sample problem presented in Figure 2, choice B and choice E both implicitly assume the continuously stirred tank reactor (CSTR) mass balance but one uses detention time or while the other uses operational time for the time parameter in the equation. Thus, if a participant chooses choice B we can determine that the participant does not understand the difference between operational time and detention time. Choices C and D both are answers obtained by using the plug flow reactor (PFR) mass balance or the first order exponential equation, but either with the detention time or the operational time for the time parameter in the equation. A ‘none of the above’ or ‘other; choice was included for most questions to allow for additional answers and therefore additional alternate conceptions. All questions also included a text box in which students were required to explain their thought process in solving the given problem to obtain the compensation for the survey. We believe that this approach will help us develop teaching methods to address these alternate conceptions.

Sample problem

Q12 What is the effluent concentration of a reactive contaminant exiting a completely mixed flow reactor after 4 hours of operation? Assume the reactor is at steady state. The volume of the reactor is 100 L and the volumetric flow rate is 50 L/hr. The influent concentration of the contaminant is 80 mg/L and the rate constant for the decay of the contaminant is 0.5 hr^{-1}.

A. 80 mg/L
B. 26.67 mg/L
C. 10.83 mg/L
D. 29.43 mg/L
E. 40 mg/L
F. None of the above
G. Describe your rationale or thought process in answering this question

Figure 2. Sample question from the MBCI written to assess the understanding of ideal reactors

IV. Preliminary Results

The multiple choice answers for each of the question in the concept inventory were coded for a specific alternate conception. The text box in which students explained their approach in solving the problem provided their thought process which was used to develop codes for additional alternate conceptions. A preliminary analysis of the results of the study showed that the concept inventory helped identify some alternate conceptions behind the incorrect answers that the participants chose. For example, students assumed first order kinetics and then used the exponential decay equation, $C = C_o e^{-kt}$, to solve for effluent concentrations in a CSTR. These students used the hydraulic detention time for t in the decay equation. The correct approach for the problem would have been to develop the mass balance equation, $dC/dt = C_{in}Q_{in} – C_{out}Q_{out} - kC_{out}V$. Both equations assume first order kinetics. However, only the second equation is applicable to a CSTR, which means that the concentration in the reactor equals the concentration leaving the reactor. In making this error, these students fail to recognize that the second equation is valid only with the average detention time for all parcels in the system as each parcel in a CSTR is thought to behave differently. This is in contrast to behavior of a parcel in a PFR, where each parcel (of fluid) is assumed to behave exactly the same way. An alternate teaching method to address this could be to explicitly teach the behavior of individual parcels in CSTR vs. PFR. In their explanations of their answers, students also stated that ‘PFRs are longer to obtain higher efficiency’ hence are larger in volume and that ‘Since PFRs have no mixing they have longer residence time’. These examples show that students are not thinking about the relationship between these parameters while working with material balance problems.

V. Conclusion and Future Work

The MBCI is currently being refined based on the preliminary results of this study. It will then be sent to faculty at other universities in the United States for validation. Upon validation it will then be evaluated by administering to students at several universities and analyzed for reliability. Thus, the final MBCI can be used as pre- (formative) and post – (summative) assessment tool in classrooms to assess student learning and evaluate teaching methods. This information will also be used to develop alternate teaching methods that specifically and explicitly address those ideas.

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Empirical Study to Determine the Educational Effectiveness of a Tool for Teaching PLC Data Access Using Open Process Control Technology

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Abstract*— Demonstration-based learning can be used to support experiential learning because it is not resource intensive, and it is relatively easy to incorporate into courses. But if demonstrations are poorly designed and/or used in poorly designed courses, demonstration-based learning can be reduced to nothing more than class entertainment. Consequently, instructors have to carefully select demonstrations that are appropriate for their courses. Moreover, it is important that instructors determine the educational effectiveness of their demonstrations so as to modify them in a way that improves learning. In this paper, we present an empirical study that we carried out to determine the educational effectiveness of a demonstration that we use to teach Programmable Logic Controller data access using Open Process Control technology, in the Advanced Components and System Integration course in the Bachelor of Technology program at McMaster University. In the study, student who had gone through OPC lectures, laboratories and a demonstration were asked to give both quantitative and qualitative feedback about their learning experience. The results indicate that the students valued the use of the demonstration tool mainly because it was *used in conjunction with the lectures and laboratories.

Keywords—Empirical-Study, Experiential-Learning, Demonstration, Open-Process-Control;

I. INTRODUCTION

It is generally agreed in literature that people learn better by doing [4, 8, 11]. Therefore, teaching and learning in the School of Engineering Technology at McMaster University in heavily based on the paradigm of experiential learning, through coop work study, laboratories, and course projects. It is in line with this teaching and learning paradigm that we have developed a demonstration tool for teaching Programmable Logic Controller (PLC) data access using Open Process Control (OPC) technology. OPC currently stands for "Open Platform Communications". When OPC was released in 1996, it was restricted to Windows operating systems, and the acronym stood for "OLE for Process Control"(OLE is an acronym for "Object Linking and Embedding") However, OPC is now available on other operating systems and is frequently implemented in fields beyond process control. As a result, the original name of OLE for Process Control or its later name of Open Process Control is no longer appropriate. As of November 2011, the OPC Foundation officially renamed the acronym to mean "Open Platform Communications". But they also use the tagline "Open Productivity & Connectivity" on their website [9].The change in name reflects the applications of OPC technology in Process Control, discrete manufacturing, building automation, and many others. OPC has also grown beyond its original OLE (Object Linking and Embedding) implementation to include other data transportation technologies including XML, Microsoft's .NET Framework, and even the OPC Foundation's binary-encoded TCP format [9].

The design and implementation of the our OPC training tool is presented in our paper titled, "A Training Demonstration for Experiential Learning in OPC Based Process Automation Data Access", Published in the proceedings of the Canadian Engineering Education Association (CEEA2013) conference. That paper also covers the process of utilizing the tool based on the principles of active-concurrent and active-prospective demonstrations, to train students in the process of setting up OPC servers and clients. Moreover, it describes how the demonstration is integrated with traditional lecturing and OPC laboratory work to support experiential learning. The focus of this paper is the empirical study that we carried out to determine the educational effectiveness of the tool [10].

The rest of this paper is arranged as follows: In Section II we present the background to using our demonstration to support experiential learning in OPC training. In Section III we present a brief overview of our tool, and in Section IV we present the empirical study. Finally, we present the conclusion and future work in Section V.

II. BACKGROUND

Demonstrations can be used to support experiential learning, if they are accompanied with activities that enable learners to discover knowledge. Such demonstrations are classified in literature as active demonstrations. Active demonstrations are of four types, namely:

- *Active-preparatory demonstrations*: These demonstrations provide activities and information to the learners before viewing the example.
- *Active-concurrent demonstrations*: These are demonstration that give pre-demonstration activities

and place activity demands on learners during the demonstration

- *Active-retrospective demonstrations*: These are demonstrations that have activities that are performed after viewing the demonstration.
- *Active-prospective demonstrations*: These demonstrations have activities that take place after the demonstration has occurred and they focus the learner on how the knowledge acquired from the example can applied to other contexts.

All these types of active demonstrations can be designed to support experiential learning by giving students initial knowledge that helps them to quickly start their own discovery. Moreover, demonstrations enable instructors to give guided discussions of examples, which increases learning by focusing the attention of the learners on the targeted knowledge areas, prompting mental rehearsal, and increasing motivation [5].

Our OPC Demonstration is used to support experiential learning as follows: Firstly, students are required to come to the demonstration tutorial after installing INGEAR Allen-Bradley OPC Server [1], KEPServerEX V5 OPC Server [3] and OPC DataHub [2] onto their laptops. INGEAR Allen-Bradley OPC Server and OPC DataHub applications are used in the active-concurrent demonstration where students follow the instructor's lead through a number of steps to access the process data in the PLC [10]. Secondly, Students are given activities that focus them on how OPC data access can be used in other contexts, using KEPServerEX V5 OPC Server and OPC Data Hub applications. Thirdly, students are required to use OPC data access in a problem-based project.

III. Brief Overview of the OPC data Access Demonstration

Our demonstration for teaching PLC data access using OPC technology uses a Micrologix PLC to control the lighting and cooling systems of a small fictitious house. In addition, the demonstration has a wireless Ethernet router that sets up a Local Area Network (LAN). This LAN enables OPC servers and PLC drivers installed on students' laptops, to access the PLC data and make it available to the OPC client (OPC DataHub), also installed on the laptops [10]. Figure 1 shows the PLC tags accessed by INGEAR Allen-Bradley OPC Server. Once this server is added to the OPC DataHub client, it is possible to visualize the data associated to the tags in the client, and to implement Human Machine interfaces as shown in Figure 2. Since the applications are not security protected, the students are able to explore and learn how symbols and icons in the OPC HMI (See Figure 2) are attached to the server tags, and how the server tags are attached to the PLC tags.

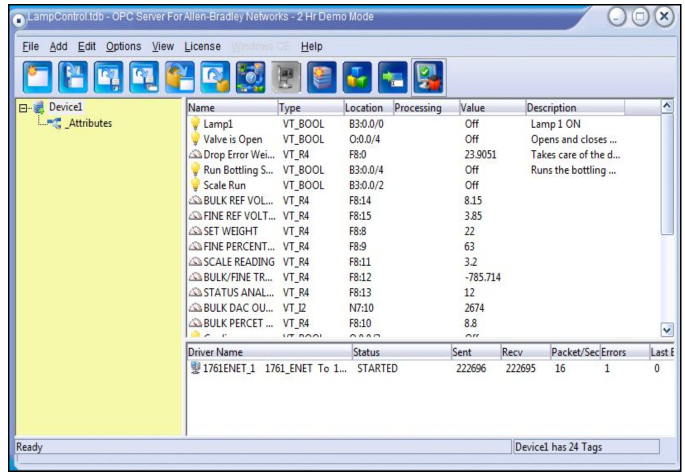

Fig. 1. PLC Tags access by INGEAR OPC Server.

III. Empirical Study

The purpose of this study was to assess the educational usefulness of a training demonstration for the configuration of Open Process Control (OPC) data access.

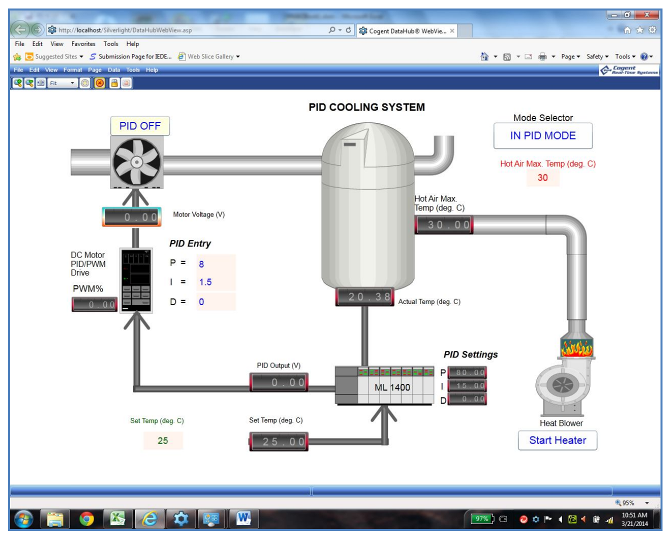

Fig. 2. Demonstration tool HMI using OPC DataHub

To achieve this purpose, we evaluated the results of a questionnaire that was administered after covering the OPC topic of the Advanced Components and Systems Integration course, and after carrying out a class demonstration of our OPC tool. Moreover, the questionnaire was administered after students had finished carrying out a class project in which they were required to use OPC data access technology. The study was approved by the McMaster Research Ethics Committee and 17 students out of a class of 42 participated in the study. The following four statements of the study questionnaire were used to collect quantitative data on how students valued the OPC data access demonstration:

- The demonstration was carried out at an appropriate time within the schedule of the Open Process Control (OPC) topic
- The demonstration tied in well the lectures, tutorial and the laboratory on Open Process Control
- The demonstration was helpful in the comprehension of Open Process Control material
- The demonstrations such as the one used in the Open Process Control topic are a good learning tool

The students were required to give each statement a score of 1 to 5, where a 1 meant that they strongly disagreed with the statement and a 5 meant they strongly agreed with the statement. In addition to the four statements above, the following four questions were used to collect qualitative information about how the students generally felt about the educational effectiveness of our OPC data access demonstration or training tool:

- What was good about the demonstration that was used in the Open Process Control topic?
- What was bad about the demonstration that was used in the Open Process Control topic?
- Comment on how the demonstration was helpful in understanding the topic material.
- Comment on how well the demonstration tied in with the topic lectures, tutorial and laboratory.

A. *Results of the Empirical Study*

Figure 3 shows the distribution of the scores given to the four empirical study statements that were used to collect quantitative data about the students' view on the educational effectiveness of our OPC training tool.

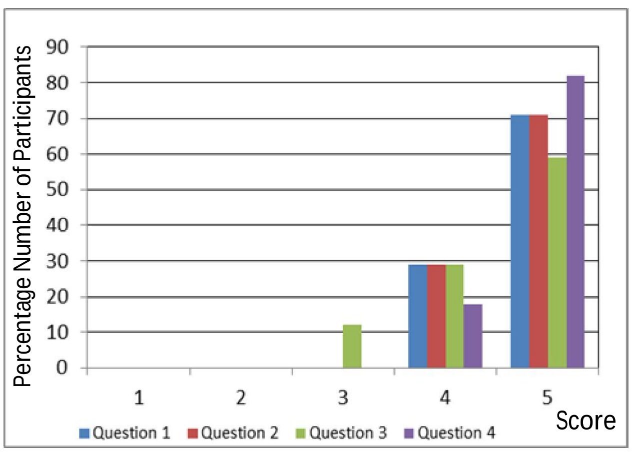

Fig. 3. Distribution of the scores given to the four empirical study statements by students

In Tables 1 and 2 we present a summary of the students' responses to questions of the study questionnaire.

B. *Discussion of Results*

The results in Figure 3 clearly show that over 85% of the students agreed that our OPC data access demonstration or OPC training tool has strong educational value, and it helped them to understand OPC data access concepts. The students also agreed that the tool was even more effective because it tied in well with the lecture material, labs and the class project (see Table 1).

Table I. Responses to the Empirical Study Questions

No.	Question	Student Responses
1.	What was good about the demonstration that was used in the Open Process Control topic?	➢ It is great for demonstrating the capabilities and flexibility of OPC technology in industrial applications ➢ It a good tool that is similar to what is in the field ➢ Helps to know how the equipment is integrated ➢ It helped to understand how the system works ➢ Demonstrated effectively the functions of OPC ➢ It provides a great opportunity to gain some insight of how OPC works ➢ Everyone with a PC could participate ➢ It is interactive ➢ Real life application ➢ Physically visualizing the importance of OPC ➢ Teaches automation and remote connection concepts ➢ It is a great demonstration with a lot of visual power ➢ It was interesting
2.	What was bad about the demonstration that was used in the Open Process Control topic?	➢ The demonstrations should have been used for all lectures ➢ It was hard to follow initially ➢ Should have given out brochures for further reading about the demonstration ➢ Being unable to see the internal components ➢ Not being compatible with Mac ➢ Should have incorporated different devices to demonstrate versatility
3.	Comment on how the demonstration was helpful in understanding the topic material.	➢ It provided visual representation of an automated system ➢ Seeing the technology in operation gives better understanding ➢ It covers foundations and applications ➢ Seeing OPC in action help me to understand the concepts ➢ It is a great hands-on tool ➢ It is well associated with the material in the lectures ➢ It is an accurate representation of OPC technology ➢ It helps to relate the lecture material to real life applications ➢ It shows how OPC is maintained ➢ The physical application helps to understand the system ➢ It helps to understand how different parts of factories are integrated
4.	Comment on how well the demonstration tied in with the topic lectures, tutorial and laboratory.	➢ Lecture cover the theory, and the demonstration helps to strengthen the material covered in the lectures. It is easier to understand something when you see it physically working. ➢ Really informative, gives very good knowledge of the lecture and lab component of the technology ➢ The demonstration fits in well with the lab and lecture material; and the brings into play, the real life application of the material ➢ Provides a brief overview of the OPC components working simultaneously, but it has much more potential to help in the teaching of OPC concepts ➢ The demonstration ties in very strongly with the course lectures and laboratories ➢ It is an effective way of showing how everything covered in the lectures and laboratory comes together in a single system ➢ It effectively bridges the theoretical knowledge and the practical application of OPC technology

The responses to question 2 in Table 1 are being used to improve the demonstration. This is in line with the general agreement in literature that people learn better if material is presented to them through multiple modes, and that different students learn better through different methods. [6, 7]. Moreover, there was a general consensus among the students that well designed demonstrations are good educational tools. It is important to note that after covering the OPC technology topic, over 20% of the students in the class modified their capstone projects to include OPC technology. In addition, the best capstone project in that class had an OPC technology component.

IV. CONCLUSSION

In this paper we present a brief overview of a demonstration tool that supports experiential learning in OPC based process automation data access. We also present an empirical study that we carried out to determine the educational effectiveness of the tool. The results of the study show that the demonstration is an effective educational tool, especially when used in such a way that ties it in with the course lecture material, labs and projects.

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Development, Teaching, and Evaluation of an Undergraduate Foundational Course in NanoElectronics

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***Abstract*—The course, which was developed, taught, and evaluated, has the following unique features: It is modular in structure. Computational nanotechnology has been made an integral part of the course. It provides hands-on experience with real samples and equipment. High Performance Computing Cluster (HPCC) has been used for modeling and simulation. The course was offered at the junior/senior level to electrical engineering majors. The main objectives of the course were to teach: The characterization and fabrication of nanomaterials, the simulation of materials and devices, the operation and design of devices, and the design and fabrication of integrated circuits, at the nanoscale. The course was taught by the four faculty members who developed the course. Students were assigned grades on the basis of in-class assignments and projects. A NanoElectronics Concept Inventory (NCI) was developed to assess student learning of fundamental concepts in the course, using a process which has been widely used for the development of concept inventories for various subjects. In NCI, the concepts were grouped into three categories: computational nanotechnology, nanoelectronics materials and devices, and nanodevice characterization and fabrication. The NCI has been administered and the scores have been analyzed using psychometric tools as well as the observed performance of students on the design projects. The results so far have been very encouraging.**

Keywords*—NanoElectronics Course, Computational NanoTechnology, Nanoscale Devices, Nanoscale Fabrication, NanoElectronics Concept Inventory;

I. INTRODUCTION

For nearly the last twenty years, nanotechnology has been advertised as the future of the electronics industry. Towards this end, many universities across the country, and around the globe, have been actively developing undergraduate nanotechnology education and research programs. While all these programs will lead to better background preparation and content of courses related to nanoelectronics, there are several challenges which lie ahead. One of them is the need to reach the widest diversity and number of students. There is a critical need to develop undergraduate nanotechnology education programs and nanoelectronics courses in universities that are not research intensive, and therefore lack the infrastructure available to larger institutions.

The other relates to the course content. It is widely recognized that understanding of fundamental concepts related to the operation of nanoelectronic devices is essential for their modeling, design, and development. These fundamental concepts are from the areas of Hamiltonian Mechanics, Quantum Mechanics, Solid State Physics, and Semiconductor Materials. It is very challenging to teach these fundamental concepts to undergraduate students in such a way that they not only have a good understanding of the concepts but also are able to apply them to solve problems associated with the design and development of nanoelectronic devices.

We have developed a senior/junior level course to teach these fundamental concepts to students in the electrical engineering major. The course is unique in the following ways: it is modular in structure; computational nanotechnology has been made an integral part of the course; it provides hands-on experience with real samples and equipment; High Performance Computing Cluster (HPCC) has been used for modeling and simulation. The paper describes the development, teaching, and evaluation of this undergraduate foundational course in nanoelectronics.

II. DEVELOPMENT AND DESCRIPTION OF THE COURSE

The course, Introduction to NanoElectronics, was developed by four researchers with expertise in the four areas corresponding to the four modules of the course [1].

A. Development of the Course

The course development was guided by the following principles:

1. Electrical Engineering students will be introduced to wide-ranging aspects of nanoelectronics through a course targeting senior/junior level students.
2. Students will be provided knowledge and skills which will enable them to participate in nanotechnology research and development work.
3. The course will be modular in structure, thereby allowing flexibility in pedagogy and easy adoption by other courses/departments/universities.
4. Suitable metrics will be developed which will enable the measurement of students' learning and effectiveness of teaching in nanoengineering related courses.

The course was divided into four modules in the areas of nanoscale fabrication and characterization, computational nanotechnology, nanoscale devices, and nanoscale integrated circuits. The content of each module was developed by a faculty member having expertise in the area of the module. Keeping in view the guiding principles, the time constraint, and the background of students, faculty members suggested tentative topics to be included in their respective modules. The topics were also selected in such a way that topics in one module provided foundation for the topics in the succeeding module. The proposed topics were then analyzed and discussed by the four faculty members. In the light of these analyses and discussions, modifications were made to the topics. After several such iterations, the topics to be included in individual modules were finalized.

B. Course Description

The course consisted of the following four modules: Introduction to Nanoscale Fabrication and Characterization, Basic Computational Nanotechnology, Introduction to Nanoscale Devices, and Introduction to Nanoscale Circuits. To understand the rationale behind the selection of the topics for individual modules, the course objectives and learning outcomes are summarized. The main objectives of this course were to teach the characterization as well as fabrication of materials at the nanoscale, the simulation of materials and devices at the nanoscale, the principles of the design of devices at the nanoscale, and the principles of the design of logic systems at the nanoscale. After the successful completion of this course, the student will be able to understand the characteristics and behavior of materials and devices at the nanoscale, to design simple logic systems at the nanoscale, and to do a research project in the field of Nanoelectronics.

A brief description of these individual modules follows.

Introduction to Nanoscale Fabrication and Characterization Module consisted of the following topics: Fabrication (Deposition Techniques, Cleanroom and photolithography techniques), Structures and Devices, and Characterization (Scanning Electron Microscopy, Transmission Electron Microscopy).

Basic Computational Nanotechnology Module consisted of the following topics: Formulation of Carrier Transport Problem, Hamiltonian Mechanics, Essentials of Quantum Mechanics, Schrodinger's Equation, Atomic Structure (Periodic Table), Crystal Lattices, Scattering, Energy Bands in Solids, Tunneling, and Semi-Classical Carrier Transport (Boltzmann Transport Equation and Poisson Equation based algorithms).

Nanoscale Device Module consisted of the following topics: Review of basic device physics, diode, BJT, and MOSFET operations, Nanotubes and nanowires – physical structure and electronic and optoelectronic properties of carbon nanotubes and silicon nanowires, Semiconductor hetero-structures, Hetero-structure field effect transistors, HBTs, transferred electron effects and NDR, Quantum wells, quantum dots and wires, Quantum dot cellular automata, Resonant tunneling and devices, Quantum Computing, molecular and biological computing, Device modeling of field-effect transistors incorporating nanotubes and nanowires – classical and semi-classical approach, and Device simulations on HPCC.

Introduction to Nano-Scale Circuits Module consisted of the following topics: Current VLSI technology (Complementary metal-oxide-semiconductor circuits, Limitations of CMOS technology at nanoscale, CMOS scaling Issues), Nanoscale Alternatives (Tri-Gate transistors, Multi-Channel Tri-Gate transistors, Gate-All-Around transistors), Electrical Properties of modern nanoelectronic FETs (Carbon nanotube, Silicon nanowire), Fabrication process issues at nanoscale, and Computer aided design and simulation tools.

III. TEACHING AND GRADING OF THE COURSE

The course was taught by the four faculty members who developed the course. A small group of Junior students with major in Electrical Engineering enrolled in the course. The instructors had personal interaction with most of these students starting with the semester, prior to that in which they enrolled, during which the enrollment campaign was conducted.

A detailed course schedule, which specified topics which were to be covered each day, was given to the students. Copies of slides and other course materials were provided. The modules were taught in the following sequence: Basic computational nanotechnology, nanoscale fabrication and characterization, nanoscale devices, and nanoscale integrated circuits.

Since the emphasis of the course was on learning the basic concepts and applying them to understand the operation of various devices, students were assigned grades on the basis of in-class assignments and projects.

IV. INSTRUCTION EVALUATION

The Instruction evaluation was done by means of surveys, concept inventory, and performance of students on research and development projects. Surveys were used during the initial offering of the course when NanoElectronics Concept Inventory (NCI) was developed.

In addition to an End-of-Course survey, surveys were conducted at the end of each module. Since the instructors had developed good rapport with the students, even before the course started, they considered themselves to be participants in the development of the course and provided valuable feedback and suggestions for the improvement. The course was well-received by the students. They agreed with the statement that the course was useful for their studies and career preparation. They indicated that, as a result of taking the course, they felt better prepared to work in the nanotechnology field. In the light of the experience gained by faculty members as well as feedback from the students, the course was revised for the subsequent offering of the course.

Another important indicator of the effectiveness of the course was the performance of students in the research and development project which was assigned to the students. The projects were group projects. Each group was assigned a real-world nanoelectronics problem.

A. NCI Development and Description

Depending on the context, availability of background material and the objectives, several investigators have adopted various processes for the development of their concept inventories. Common among all of these processes are two major steps: specification of fundamental concepts and development of multiple choice questions related to these concepts. The NCI was developed by using this two-step process [2].

Researchers identified fundamental concepts in their individual modules. The compiled list of all the concepts was reviewed by all the researchers to make them consistent and to eliminate any redundancy which may be present. After a few iterations the following concepts were considered to be fundamental to the nanoelectronics course which was proposed and taught:

Computational NanoElectronics concepts: Conservative Force, Hamiltonian, Wave-particle Duality, Quantization of Energy, Uncertainty Principle, Schrodinger's Equation, Pauli's Exclusion Principle, Quantum Mechanical Tunneling, Four Quantum Numbers, Energy Bands, E-k Diagrams, Fermi energy, Fermi Function, Work Function, Drift, Diffusion, and Boltzmann Transport Equation.

NanoElectronics Devices concepts: Band Diagram, Band Bending, and p-n junction.

NanoElectronic Fabrication concepts: Deposition, Lithography, Etching, Implantation, MOSFET operation, Complementary Logic, Scaling, and Nanowire and Nanotube Fabrication.

After finalizing the concepts, researchers formulated the multiple choice questions. Researchers relied upon their experiences to select the distractors. These distractors will be further refined as more experience is gained with teaching of the course and supervision of design projects.

The NCI consists of 24 questions. The first 13 questions are on computational nanoelectronics concepts, the next 4 questions (questions 14 thru 17) are on nanoelctronics devices concepts, and the final 7 questions (questions 18 thru 24) are on nanoelectronic fabrication concepts. Questions 1 thru 13 deal with the following concepts: conservative force, Hamiltonian, wave-particle duality, quantization of energy, uncertainty principle, Schrodinger equation, Pauli Exclusion principle, quantum tunneling, energy bands, Fermi energy, drift, diffusion, and Boltzmann equation. Question 14 deals with the effect of doping on band diagrams, 15 with the effect of applied potential on band diagrams, 16 with the production of current, and 17 with the operation of Field Effect Transistor. Question 18 deals with layout and mask transfer, 19 with CMOS architecture, 20 with scaling obstacles, 21 with the effect of scaling, 22 with material etching, 23 with material properties, and 24 with the role of depositions in fabrication processes.

B. NCI Administration and Results

The NCI was administered to a small group of students after taking the Introduction to Nanoelectronics course. The results were consistent with the grades obtained on the basis of in-class assignments, projects and exams. The results were further validated by the performance of the students on the projects. Since before taking the course, students were not exposed to any of the subject matter taught in the course, it is reasonable to assume that their knowledge of nanoelectronics was entirely due to the instruction which they received.

As more data are collected by the administration of NCI, it will be possible to establish more rigorously its reliability and validity using classical test theory and item response theory [3, 4]. Additional studies, similar to that reported by Herman and Handzik [5], can be carried out for improving pedagogy of nanoelectronics courses.

V. Conclusion

A new approach to teaching a first course in nanoelectronics has been presented. Recognizing that the modeling and simulation plays a very significant role in understanding the operation of electronic devices at the nanoscale, basic computational nanotechnology has been made an integral component of the course. Students have been introduced to computational nanotechnology from the ground up, that is starting from the basic postulates and concepts of quantum mechanics and solid state physics. Students actually carried out the simulations using High Performance Computing Clusters. The modular structure of the course provides enough flexibility to instructors to adapt the course to the educational environment in which the course is being taught. The feasibility of this approach has been demonstrated by teaching the course to a small group of students at Texas A&M University-Kingsville. Further refinement of the course structure, the course content, and the teaching technique are planned for the future.

Acknowledgment

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How to Measure the Quality of Teaching by Graduate Assistants in Undergraduate Engineering Courses

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***Abstract*— As part of the development of student-centered graduate assistants for undergraduate engineering courses, Student Evaluations of Graduate Assistants/Teaching Assistants (SEGATAs) have been piloted at the University of Windsor. Based on the initial feedback received regarding the SEGATA survey, starting in the Fall 2014 semester, all courses within the Mechanical, Automotive, and Materials Engineering (MAME) department will ask students to complete the SEGATA survey for the graduate assistants (GAs)/teaching assistants (TAs) responsible for their courses. As Canadian undergraduate engineering programs move towards an outcomes-based curriculum that requires the implementation of a continuous improvement process, enabling GAs to receive feedback regarding their teaching skills will further add to the improvements that can be achieved for the undergraduate curricula. As well, the GAs/TAs who receive the SEGATA feedback can use this information to build up their teaching dossiers as they are completing graduate school while also providing professional development of instructional skills. Furthermore, it allows course instructors to assess the quality of student learning under the GA's/TA's guidance, their role in facilitating that learning, their strengths, and areas in need of development.**

This paper will discuss the lessons learned from the pilot of the SEGATA survey and how the survey has developed to better serve the needs of those providing the feedback and those receiving the feedback.

Keywords—performance evaluation, performance review, feedback, continuous improvement, teaching dossier;

I. Introduction

The undergraduate learning experience is partly influenced by the effectiveness of the graduate and teaching assistants that are involved in lecturing, running laboratory sessions [1]. The Curriculum-Instruction-Assessment (C-I-A) triad, as shown in Figure 1, is used as a core model for understanding how knowledge is transferred from and between the instructor and graduate assistants (GAs) or teaching assistants (TAs) and to the students. The role of the GAs and TAs in teaching and learning activities should be recognized. In the context of large classes especially, their ability to assist the instructor has a great impact on how students meet the desired learning outcomes. The outcome of the education and students' achievement is measured by variable assessment methods [2].

GAs and TAs are responsible for an array of tasks and duties to assist faculty members whether through direct face-to-face interactions during lab sessions and tutorials or indirect interactions through emails, course designated websites or on-line learning environments.

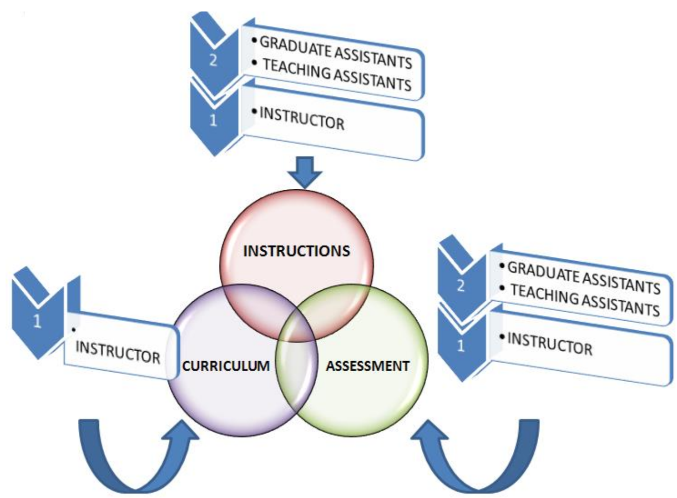

Fig. 1. The C-I-A Triad and the GAs'/TAs' relationship to it.

GAs/TAs have responsibilities in two of the elements of the triad: instructions and assessment. It is crucial to assess their performance in these elements due to impact it has on the students' learning experience and achievement of the learning outcomes. Five graduate assistants were assessed for the Advanced Engineering and Design course offered to second-year Mechanical Engineering students at the University of Windsor.

The course instruction consists of teaching and learning activities that are used to help students develop their understanding of the course content as indicated in the outcomes-based curriculum. The instructions are transferred to the students by the instructor during class and laboratory activities, but also by the GAs/TAs during laboratory periods and office hours.

The assessment of learning outcomes is performed using different methods. In this course, bi-weekly progress tests helped the instructor to gauge students' performance. Formal midterm and final exams were also used. These tests, along with assigned course projects, prepared the students to demonstrate their level of critical thinking, problem solving skills, communication skills, and team work.

As shown in Figure 1, GAs and TAs also have a crucial role in the assessment of students' learning outcomes. They are provided with marking rubrics for each type of assessment and they are asked to assess the students' work. Each GA/TA must be familiar with the course content, have the ability to supervise five to seven design teams, and provide feedback to the students.

It can be concluded that the quality of teaching and learning depends on the GAs' or TAs' performance. It is important to have graduate assistants with beliefs and perceptions aligned with the instructors' teaching goals [3] and also students' learning outcomes. The challenge consists in assessing the GAs'/TAs' performance in relation to the outcomes-based curriculum, for the purpose of improving the quality of engineering education.

Through analogy, it only seemed appropriate to measure the effectiveness of their role in students' teaching and learning experiences using a tool similar to the student evaluation of teaching (SET) survey used to evaluate the instructors.

The use of surveys to evaluate instructors is a standard technique used at many institutions of higher education. As reported by Wachtel [4], several universities in the United States started implementing SETs in the 1920s. In general, SETs have been used for the following purposes [5]:

- to enable teaching development for instructors, based on student feedback;
- to measure instructor performance for personnel decisions;
- to help students in deciding their courses and instructors; and
- to provide data for studies regarding teaching.

Although there may be differing purposes for using SETs, it is generally non-controversial to employ the results as formative feedback to instructors [6].

With formative feedback as one goal, Student Evaluations of Graduate Assistants/Teaching Assistants (SEGATAs) have been piloted at the University of Windsor in the Engineering and Design courses, starting in the Fall 2013 semester. The Mechanical, Automotive, and Materials Engineering (MAME) department at the University of Windsor is implementing SEGATAs in the Summer 2014 semester, and it is expected that the use of these evaluations will be extended to all of the Faculty of Engineering, starting in the Fall of 2014.

Furthermore, it is expected that the use of SEGATAs will aid in continuous improvement efforts within the departments and will also provide information for GAs and TAs to be included within their teaching dossiers. As shown in Figure 2, characteristics relating to knowledge, communication skills, and professionalism are measured by the survey results. From this perspective, the intended goal is to shape teaching and learning skills for future faculty, and to create a set of transferable skills for those who will not pursue a career in higher education.

The instructor plays a major role in this process. The new evaluation and the continuous effort to improve the quality of the students' teaching and learning experience require the instructor to provide the necessary training to their GAs/TAs and to examine and assess their performance.

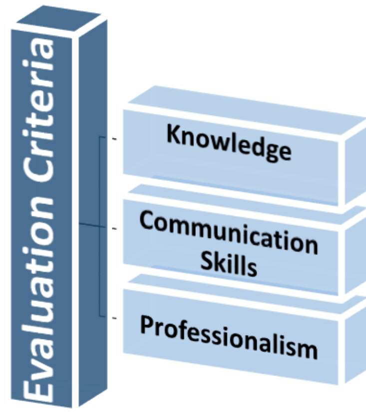

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Fig. 2. GA/TA characteristics evaluated by the SEGATA survey.

II. Methodology

The SEGATA survey was developed in collaboration with IT Services at the University of Windsor. This evaluation process was tested during a pilot run in the Advanced Engineering and Design class. Participants were second-year engineering students. There were five graduate assistants assigned to this course. Both parties, the students and the graduate teaching assistants, were informed about this survey and the purpose of the evaluation at the beginning of the semester:

- For the students: to provide feedback regarding how the GA/TA contributed to their learning experience in this course, in order to achieve the desired learning outcomes.
- For the GAs/TAs: to use the feedback to improve their teaching skills, their leadership skills, and their ability to communicate and manage conflicts.

In addition, administrators and instructors will use this information to make personnel decisions regarding future GA/TA position offerings, and to monitor overall departmental teaching effectiveness.

A. The Evaluation Form

A link to the online survey was provided to students through the course web site within the learning management system used by the University of Windsor, Collaboration and Learning Environment Windsor (CLEW).

Within the first section of the survey, students are asked nine questions in which they provide a Likert rating between 1 (Very Poor) and 5 (Very Good), or 6 (N/A) for each GA/TA. The first 8 questions were designed to measure the GA's/TA's knowledge, communication skills and professionalism, as indicated in Table 1. Question 9 asks the students to rate the overall effectiveness of the GA/TA, and Question 10 is a yes/no question that prompts students, "I would like to have this GA/TA again."

Table 1. GA's/TA's characteristics as assessed by Questions 1 to 8.

Characteristic	Survey Questions
Knowledge	Q1. Was the GA/TA knowledgeable and prepared for the topic?
	Q2. How helpful were the comments /feedback on student work?
Communication	Q3. Was the GA/TA a clear and effective communicator (i.e., answering questions, explaining topics,…)?
	Q4. Did the GA/TA create a positive environment that encourages open discussions and questions?
Professionalism	Q5. Was the GA/TA approachable for additional help?
	Q6. Was the GA/TA accessible for individual consultations (by e-mail and/or in office hours)?
	Q7. How fair was the grading of student work (did the GA/TA follow the marking scheme)?
	Q8. How timely was the grading of student work?

The second section of the survey provides space for students to submit written responses to three prompts:

A) What did the GA/TA do that most assisted with your learning?
B) What changes would you suggest that will help your GA/TA to improve his/her effectiveness in the future?
C) Other comments.

The comments from the second section provide valuable feedback for the GAs/TAs and the instructor, and will be used to redesign some aspects of the course, for example, the number of students assigned to each GA/TA.

B. *The Evaluation Process*

Each student was asked to complete the survey for the GA/TA assigned to him/her for the course. To access the survey, students can use their computers, iPhones, iPads or android devices; the survey is accessible to the students through the CLEW website during the last two weeks of classes for the semester.

The SEGATA survey is designed to allow the course instructor to customize it with a drop-down list of the GAs/TAs assigned to his/her course, the course number, and the semester that the course is offered.

After all responses have been received, it is each instructor's responsibility to provide each GA/TA with a summary of the evaluation results in the Summary Regarding SEGATA Results and Instructor's Feedback document, which is made available for each instructor.

A review session with the instructor is scheduled with each GA/TA. This is an opportunity to go through the gathered results. During the review session, the result of the students' feedback is shared anonymously with the graduate students. This feedback assists the GAs/TAs with an improvement plan. They can use the students' and instructor's feedback to improve their teaching skills, their leadership skills, and their ability to communicate and manage conflicts. To keep track of their progress, GAs are required to include the assessment in their teaching portfolio.

In addition, administrators and instructors will use this information to make personnel decisions regarding future GA/TA position offerings, and to monitor overall departmental teaching effectiveness.

III. Results

During the Winter 2014 offering of Advanced Engineering and Design, there were 140 students registered in the class working with five GAs. Only graduate assistants were assigned to work with the instructor for the semester under consideration (e.g., there were no TAs for the course). Preliminary results from the pilot semester indicate a high response rate of 83%, with an 89% completion rate was achieved, and that the average time to complete the survey was about one and a half minutes.

Selected results of the pilot survey are shown in the diagram presented in Figure 3 and Figure 4. Figure 3 shows the overall effectiveness of all GAs assigned to the Engineering and Design class, based on the answers to Question 9.

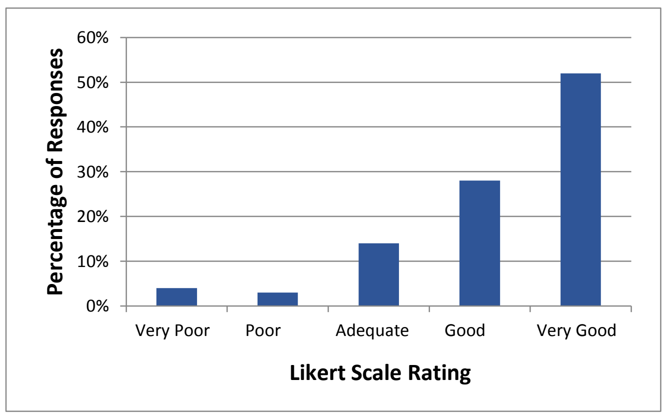

Fig. 3. GAs' overall effectiveness

From Figure 3, it can be concluded that 80% of the participants ranked the overall effectiveness of the GAs good and very good.

For the purpose of individual assessment, the instructor analyzed the results provided for the first eight questions to obtain pertinent information regarding the desired learning outcomes for each GA. The sample results shown in Figure 4 are based on answers provided by the students on questions mentioned in Table 1, and indicate one GA's performance in each of the three characteristics under consideration: knowledge (Q1, Q2), communication (Q3, Q4), and professionalism (Q5, Q6, Q7, Q8). The GA under consideration was assessed by the students to whom he/she was assigned and which represent 25% of the total number of students in the class. It should be noted that the percentages listed relate to the average rating for the GA on the 1 to 5 scale, with 100% being equal to an average rating of 5.

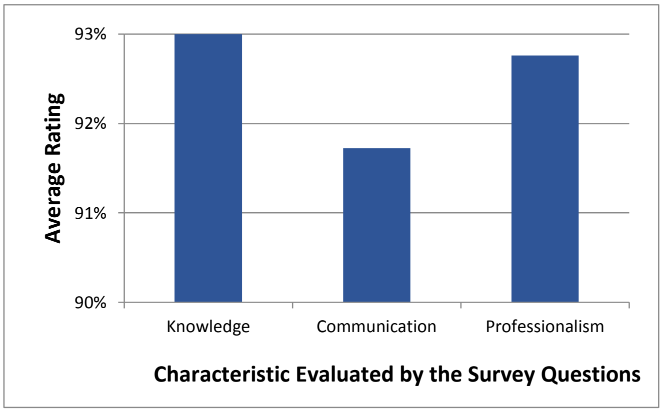

Fig. 4. One GA's performance in relation to the characteristics relating to knowledge, communication, and professionalism.

The average performance of all GAs for Questions 1 to 8 was also analyzed, and the results are shown in Figure 5.

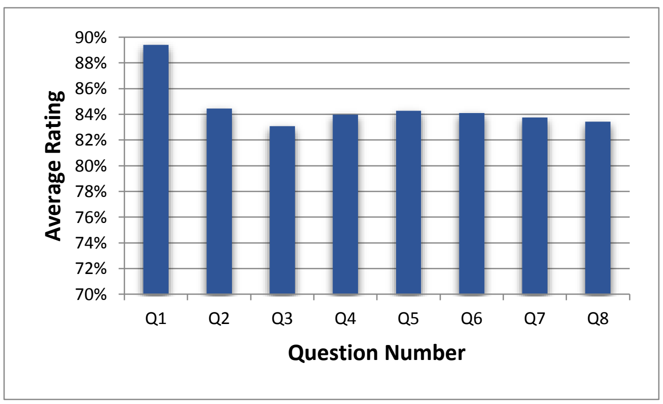

Fig. 5.Average rating for all GAs for questions one to eight of the survey.

IV. CONCLUSIONS

The surveys revealed students' perceptions about their GAs' knowledge, communication skills and professionalism. This evaluation process enables the instructors to track their GAs' performance and provide them with strategic plans to overcome their weaknesses and enhance their strengths. Graduate assistants will use the provided feedback as a development plan to empower their teaching skills by taking related courses or workshops [7] and self-reflections [8].

Based on the authors' experience piloting the survey, it is concluded that this initiative should continue. The GAs/TAs were provided with valuable feedback regarding their effectiveness in their roles within the course. The MAME department at the University of Windsor also recognizes the relevance of this activity for development and continuous improvements for GAs/TAs as well as for the program curriculum. The intent is to support this practice to be adopted widely, since it gives valuable information to the instructors, to the graduate and teaching assistants, and also for administrators considering means for collecting data for the purpose of assessing outcomes-based education. The SEGATA survey will be implemented by the entire Faculty of Engineering during the Fall 2014 semester.

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From ‘quality’ assurance to ‘quality enhancement’: Addressing the transition from ‘teaching’ to ‘learning’ in engineeering education

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***Abstract*—Quality assurance programs are now commonplace in higher education. Although widespread, Newton (2002) points out that such top-down quality assurance systems are both under-researched and under-theorized. This paper is an attempt to identify the key dimensions of quality assurance and quality enhancement programs and to investigate their application in one engineering course at a Norwegian university. The aim is to contribute to conceptual clarification, and in particular to clarifying decisions made in relation to ‘quality assurance’ and/or ‘quality enhancement’, drawing upon insights gained from a conceptual model devised by the author. To investigate the course under review, the author collected data from a student group, reviewed the teachers’ course review, and inspected students’ learning achievements in the form of their examination results. The result was to identify consequences, both intended and unintended, of using the institutional quality assurance procedures. By considering the outcomes for teachers and students, rather than relying on the stated aims of quality assurance procedures, the author makes a case for shifting the focus from ‘quality assurance of teaching’ to ‘quality enhancement of learning’ and offers recommendations for others undertaking similar quality assurance procedures in the future.**

Keywords—Quality assurance, quality enhancement, learning outcomes.

I. INTRODUCTION

Quality assurance programs at institutional level are often run by senior managers with little, if any scholarly support. The aim of this study was initially to explore the effects of a quality program on teaching and learning. With this as the empirical backdrop, a conceptual model is presented, featuring key dimensions to consider in quality programs. The model encourages explicit and grounded decisions rather than relying on tacit assumptions. A focus shift from looking at ‘quality assurance of teaching’ to aspiring to ‘quality enhancement of learning’ uncovered interesting new territory to consider. Furthermore, the application the model demonstrated the need for shared interpretations of key concepts, such as ‘teaching’ and ‘learning’. They are not self-explanatory and are likely to cause confusion at later stages if participants are not acting from shared interpretations. While the case study was conducted in one course, the conceptual model is generic and therefore is capable of general applicability.

Quality assurance procedures can have complex combinations of aims, including making higher education more of a worthwhile experience for more students, dealing more effectively with diversity, enhancing institutional reputation, maintaining academic standards, and managing ambitious learning objectives. However, as Newton points out, we cannot assume that the rhetoric of quality assurance, often derived from systems devised by senior managers, matches experiences ‘on the ground’ when applied to the teaching and learning experiences in classrooms. Newton comments:

What is surprising is that, even though ‘quality’ has had such a profound impact on academics’ lives and behaviours, […] this major transformation remains curiously under-researched and under-theorised. Indeed, if we were to stand back as an academic community and ask ‘what has been learned? and by whom?’, or ‘what has improved?’, though many would be quick to provide answers, in reality we can point to very little research into how ‘quality policy’, or other areas of strategy designed to improve learning and teaching have been used, how this has impacted on academic practice [1].

The context for this study was one where ‘quality assurance (QA)’ procedures were imposed to meet national requirements and demonstrates the emergence of public management ideologies in higher education. Senior managerial staff played a key role in the overall design of the QA program and in its implementation across the institution. Power for design and implementation rested with senior managers, resembling models found in industry-based environments, where workers obey directives from senior managers with minimal, if any, impact on the requirements which are imposed on them. Anecdotal evidence suggests that frequent casualties of accountability are improvement and active promotion of innovation. Another typical feature is to leave limited, if any, space for academics to decide their own procedures, including data analysis and potential changes.

Quality assurance procedures under review involved a third/fourth year engineering course with 30 enrolled students, offered in a Norwegian university. While officially never being involved in the process myself, I took an interest in the data collection instruments, including analysis of data and the implementation of measures. I thought this would be relevant to my substantive position as an educational researcher. I wondered if efforts invested by those in charge could be justified by evidence of outcomes. Furthermore, how might data, if it became apparent be used to improve student learning? The research questions in relation to the course under review here are:

- In what way is the quality assurance system implemented in the selected course?
- To what degree is data suitable to the task of facilitating educational development?
- What is the effect on a quality system of a shift from focusing on teaching to one which considers the quality of learning?

In particular, I wished to surface the tacit assumptions being used by students and by teachers in order to confirm or challenge the claim made by one commentator, Biggs, about the unintended consequences of using top-down, managerial quality assurance systems: 'In short, some QA [Quality Assurance] procedures have the opposite effect to that intended. This approach […] is […] not functionally concerned with the quality of teaching and learning, but with quantifying some of the presumed indicators of good teaching and good management' [2]. As seen, Biggs makes a distinction between 'teaching' and 'learning', and he points to attempts at measuring and reporting on the 'quality' of these phenomena. In order to check which of the two, whether the teaching or the learning, is being measured, investigators need to devise valid and reliable data collection instruments. For example, any investigation of 'quality' needs to decide the object of the investigation. Given the complexity of the task, only certain aspects of the construct can realistically be investigated at one time. The point is to ensure a good match between the object of investigation and data collection instruments. Otherwise, the risk is to miss out key variables when it comes to the analysis. Later in the article I will later introduce a conceptual tool that I think can be beneficial in the planning process as well as in data collection and analysis phase of any quality program.

II. Data Collection

The first source of data was a small group of three students, created by the teachers but mandated by quality assurance procedures. The aim of the student sub-group was to act as a connecting link between the full group of students and teaching staff. By interacting with the sub-group, the teacher could monitor progression and identify issues, then make adjustments during the course as necessary. The sub-group submitted two brief reports, one mid-term and one at the end of the course where students summarized discussions and suggestions arising from the course. Since there were two professors teaching the course, survey items were identical, and students were encouraged to add comments and to outline improvements. Headings included: 'course information', 'relevance', 'lectures', 'laboratories, 'teaching assistants', 'exercises', 'literature/lecture notes' and 'workload'.

A second source of information was the 'course report' which was a compulsory document written by the professor in charge of the course. This form addressed administrative matters such as the number of students in the course, name of lecturers, lecture plan and schedule of tutorials, failure rate and final grade distribution.

A third source of data was the final examination results for the cohort. My investigation of grades was motivated by an interest in learning outcomes, and I wanted to see whether there was a correlation between the sub-group's rating of the course and the overall cohort's performance as at the examination. It is of course a non-trivial task to acquire a fully valid and reliable measure of achievement; however, the interest here is to identify distributions and patterns of achievement.

III. Analysis of Data

Survey items were assumed to recognize key aspects of the course, but in short, only a 'delivery' perspective was identifiable. The same applies for the sub-group's comments and suggestions, which were shaped by focus and structure of survey items, as seen below:

<u>Comments reported at mid-term:</u>

- Exercises good and relevant
- There should be a motivation/introduction before lecturing each subject
- Relevans i forhold til læringsmål er gode. Alle punkt læringsmålet er fulgt
- Information provided in its learning works fine
- Very good lectures with clear pronunciation, good structure, it's good to see that the lecturer approaches students directly with questions, easy to follow the lecture due to explanations and deductions.
- Tasks addressed in the tutorials are relevant both in relation to objectives and lectures
- Good follow-up
- The course book is okay […]
- Workload is okay […]

<u>Comments reported at end-of-term:</u>

- Handwriting very beautiful
- Sporadic lecture notes. Could be a bit more organized
- If we have TA-time at a dedicated room more people might come
- Reorganize compendium to prevent jumping back and forth
- Handouts in the second part should also be submitted to 'its learning'
- Questions to students during lectures could be more suited to the students' abilities
- Overall good feedback on the lectures

As demonstrated above, students' comments are generally positive and raise few, if any, concerns about the 'quality' of the course. Students made brief statements on a range of issues; however, with no analysis of any aspect that might be labeled as learning. The nature of changes suggested was that of 'fine-tuning' of current practices rather than of any 'radical revision' of the course. In both the student sub-group report and the teacher course report, comments were rooted in a 'teaching paradigm' rather than in a 'learning paradigm' [3], and referred to issues of quality assurance rather than quality enhancement. Focus was on 'delivery' while issues of learning were omitted. The underpinning approach appears as a combination of the two dimensions - 'teaching' and 'quality assurance'. This is fair enough; however, confusion is caused by negligence of the limitations of the underpinning model. It is of course a far more ambitious aim to measure 'the quality' rather than one specified aspect of 'quality'. While university managers advocate the adoption of a learning approach, the quality program operates within the old paradigm of 'teaching'. That is my interpretation since no reference is made to learning either in policy documents or in responses to these documents.

Survey data generally confirms the positive impressions conveyed in the students' comments (Table 1). All items are rated positively, and workload seems just about right. From a 'quality assurance of teaching' perspective, data presented in Table 1 look rather convincing. Methodological concerns may still be raised regarding the size of the sample with only 3/30 represented in the response group. Furthermore, anchor points are not really true extremes and the term 'good' might as well mean something mediocre as something 'very good'. Judgments are subjective, making it difficult to draw substantive conclusions from this kind of 'satisfaction study'.

Table I. Survey conducted twice, 05.10 (x) & 23.11 (o)

Assessment of:	Good				Bad
Relevance (rel. to objectives)	x, o				
Course information	o	x			
Lectures	o	x			
Exercises	x	o			
Laboratories					
Counceling/follow-up	o	x			
Teaching assistants	o	x			
Literature/lecture notes		x, o			

Workload (put a mark):	Huge		OK		Low
Absolute (12 hrs. a week norm)			x, o		
Relative to other subjects			x, o		

If we consider the totality of data collected, there appears to be little substantive information about urgent needs to be addressed. Text provided was descriptive rather than analytical, and featured limited scope for changes that would make a difference to learning. While students' satisfaction was recorded, their learning achievements were not considered to be part of the quality program. To be fair, grade distributions and failure rate were requested in the final course report, but of course this does not tell the whole truth since the allocation of raw scores are often adjusted to fit anticipated and 'acceptable' grade distributions. Attempts at checking students' apparent satisfaction with the course were futile, since justifications never touched upon learning achievements. Reference points resided within the heads of the students and were never made explicit, so in theory anyone is free to make his/her own interpretations of available data. One observable effect was the teachers' negligence of the entire package of data provided by the sub-group. One professor confirmed that nothing had been done, or would be done. They regarded the quality program as an imposed administrative project from which they could not escape, and therefore ended up with some kind of compliance behavior in response.

Student achievement evidence in the form of examination results gave no support to the claim for good quality teaching and/or for good quality learning. The careful analysis of raw scores assigned at the final exam uncovered serious issues that for obvious reasons were out of focus in the applied quality framework. While the final pass rate was 80, this percentage was halved by requiring a minimum pass threshold level in each of the sub-sections. By raising the pass threshold to 50 points, only 13 % would pass the course, which is not very impressive. Students may have been awarded a pass on false grounds, and the score combination rule based on score totals violates the principle of 'grade integrity' [4], and adds to the risk of graduates committing mistakes in the execution of future work-related tasks. Applying a different combination rule would increase reliability; however, if grades are to accurately reflect achievement, then other interventions would be needed. This would include a revision of learning objectives, and ensure learning activities and exam questions are aligned [5]. More fundamental questions would be to consider the nature and purpose of the course, for example the balance between conceptual and computational learning.

In summary, the quality assurance procedures addressed the need for the university to be seen to be accountable. However, there was no evidence that they were effective, that they met the stated aims of enhancing students' experiences or of guaranteeing standards. The analysis of performance scores confirm that several different issues of learning and course design are in urgent need of attention and that the quality program (unintentionally) covers up realties of learning. My explorations convinced me of the need for greater awareness in the selection and justification of quality programs. Indeed, such programs may serve widely different purposes that all can be justified in their own right, but they cannot serve all purposes simultaneously.

Based on insights gained in this study, I took the opportunity to create a conceptual tool that aspires to be used generically. The matrix (Figure 1) consists of four quadrants, each with unique requirements, as focusing on 'learning' or 'teaching' in combination with a specified purpose as either 'quality assurance' or 'quality enhancement'. This matrix could be used to check the focus and purpose of current instruments as well as to devise instruments for future purposes, as demonstrated in the four quadrants. Terms used in the matrix are far from fully self-explanatory; however, this calls for consensus-seeking strategies. The interpretation of dimensions suggested in the matrix is not entirely straight forward and calls for a scholarly rather than a managerial approach. Everyday terms such as 'teaching' and 'learning' may take on different meanings and do not make sense unless people agree on their interpretations.

The matrix also enables the construction of instruments to meet rather diverse needs. One just needs to be conceptually aware of focus and purpose by clarifying issues of 'why', 'what' how' and 'when'. We have explored the relationship between the quadrants 1 and 3, but there could be many other combinations, for example the relationship between 3 and 4.

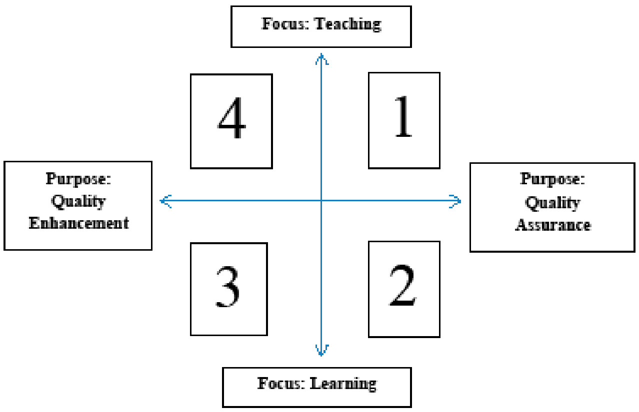

Fig. 1. Aims in quality management.

IV. Conclusion

This study shows the importance of a sound conceptual framework capable of clearly identifying targeted areas in relation to 'purpose' and 'focus. In this study, 'quality assurance of teaching' was the purpose, while the interpretation and use of data was assumed rather than scholarly based. The focus shift from 'teaching' to 'learning' and from 'quality assurance' to 'quality enhancement' uncovered a rich domain to explore. This involved the closer analysis of 'learning' and 'enhancement'. While these may seem pretty straight forward a first glance, experience may suggest otherwise. The same applies for 'teaching' and 'quality assurance'.

A generic challenge in any evaluation relates to the use of 'criteria' and 'standards'. These terms are often used interchangeably, but refer to different realities and should not be confused. If quality programs are imposed by external decisions without proper involvement of key players internally, institutions run the risk of failing support from academic staff and students. In the worst case, quality programs with the best of intentions inadvertently may do a disfavor to their institution. One way to avoid this is to become more reflective and grounded in the selection of focus and purpose of the program. The current study was carried out in one single course, but the model presented is generic and therefore is capable of general applicability.

V. Questions for Discussion

- How do delegates assess the worth of the conceptual model presented in this paper?
- How can quality initiatives in higher education become more scholarly in their approach?
- To what extent can the application of 'satisfaction studies' be useful as part of 'quality assurance'?

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ASSESSMENT OF ENGINEERING COURSE OUTCOMES: CASE STUDY

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***Abstract*—The implementation of the new ABET Engineering Accreditation Criteria 2000 (EAC 2000) into Civil and Environmental Engineering undergraduate curricula has been critical to the success of the education program. The EAC 2000 emphasizes an outcome- based system approach to engineering education where graduates must have demonstrated abilities (A-to-K), in math, science, engineering, design, teamwork, ethics, communication, and life-long learning. Although the student grades obtained may be a reflection of the course success and standard questionnaires are also employed to monitor the student feedback, little has concerned how to equip students with the skills and attitudes specified in those outcomes. The authors describe, in details, the development of an Excel spreadsheet and the associated assessment tools for a technical design course to measure its success and ensure its continuous improvement to meet the requirements of the ABET engineering criteria. Mapping of course outcomes to the Civil Engineering program (CE) objectives and outcomes and mapping of the course contents to criteria (A-to-K) are also discussed.**

Keywords*—Assessment tools, Quantitative assessment, Qualitative assessment, ABET, Measuring outcomes;

I. INTRODUCTION

To comply with the ABET engineering accreditation criteria, a program must formulate [1]: i) a set of program educational objectives that address institutional and program mission statements and are responsive to the expressed interests of various groups of program constituencies, ii) a set of program outcomes that specify the knowledge, skills, and attitudes program graduates should have in order to achieve the program educational objectives and encompass certain specified outcomes, iii) an assessment process for the program outcomes, iv) results from the implementation of the assessment process, and v) a sound plan for continuous program improvement using the results of the assessment process. Therefore, assessment is becoming a primary focus in engineering programs and institutions. This is due in part to pressure from industry, academic accreditation entities, and government agencies to incorporate competitive environment of student learning outcomes and sound assessment techniques into education programs and courses. It is, therefore, crucial to adopt a rationale methodology to assess the achievement of the ABET A-to-K educational outcomes [1], listed in Table 1, that are relevant to various engineering courses. As a result, there has been an increased interest in assessment methodologies and research within the engineering educational community. As validated assessment methods begin to appear, there is a strong need to integrate them into adaptable and accessible system applications that must become an essential component of the engineering learning environment. However, the potential of the assessment to improve instruction depends strongly on how well engineering faculty understand it and appreciate the extent to which their full involvement in it is crucial.

The assessment study by Light [2] of Harvard students indicates that one of the crucial factors in the educational development of the undergraduate is the degree to which the student is actively involved in the undergraduate experience. Light' studies suggest that curricular planning efforts will reap much greater payoffs in terms of student outcomes if more emphasis is placed on pedagogy and other features of the delivery system, as well as on the broader interpersonal and institutional context in which learning takes place. Triangulation (using multiple methods to obtain and verify a result) is an important feature of effective assessment [3]. The more tools used to assess a specific program outcomes or course learning objectives, the greater the likelihood that the assessment will be both valid (meaning that the chosen assessment method is actually matching what is supposedly being assessed) and reliable (the conclusion would be the same if the assessment were conducted by other assessors or re-conducted by the same assessor). Carter et. al. [4] provide guidance on how to meet ABET Criterion 2. They suggest that programs seeking accreditation assemble university, college, and program/department mission statements, define the key stakeholders in the program (e.g., students, faculty, alumni, employers of program graduates, and funding sources), solicit their input on desirable program attributes, and write educational objectives that take into account the various mission statements and stakeholder desires. Their guidance did not concern course objectives and assessment. Understanding the engineering criteria is not an easy task since the jargon they contain (objectives, outcomes, outcome and performance measuring, etc.) is dense and confusing, and universally agreed upon operational definitions of the terms do not yet exist. Moreover, while most discussion in the literature has focused on how to assess program outcomes (more specifically, of outcomes A-to-K), relatively limited attention has been given so far to the central role of the individual faculty member in attaining those outcomes, that is at the course level.

Since the work of equipping students with the attributes specified in program outcomes must be conducted at the individual course level, all faculty members involved in teaching courses are expected to be involved in the accreditation process on a continuous basis. For every course in the program, observable outcome-related learning objectives that are guaranteed to be in place regardless of who happens to teach the course should be defined and assessment methods for each core objective should be identified [5]. Each of these learning objectives should map onto one or more program outcomes, and all program outcomes should be addressed by objectives in several core courses. The primary purpose of the current paper is to introduce a technique for assessment of individual course outcomes in relation to the A-to-K program outcomes.

Table 1. A-to-K ABET Educational Outcomes

Educational Outcome	Description
A	An ability to apply knowledge of mathematics, science, and engineering.
B	An ability to design and conduct experiments, as well as to analyze and interpret data.
C	An ability to design a system, component, or process to meet desired needs.
D	An ability to function on multi-disciplinary teams.
E	An ability to identify, formulate, and solve engineering problems.
F	An understanding of professional and ethical responsibility.
G	An ability to communicate effectively.
H	The broad education necessary to understand the impact of engineering solutions in a global and societal context.
I	A recognition of the need for, and an ability to engage in life-long learning.
J	A knowledge of contemporary issues.
K	An Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

II. DEVELOPING CE PROGRAM OBJECTIVES AND OUTCOMES

A major consideration in the evaluation of any engineering program seeking accreditation/re-accreditation is the quality and performance of the students and graduates of the program. This requires the program to continuously evaluate and monitor students and graduates to determine its success in achieving its objectives and outcomes. The Program Educational Objectives are defined by ABET as the broad statements that describe the career and professional accomplishments that the program is preparing graduates to achieve a few years after graduation. Meanwhile, Program Outcomes represent shorter-term narrower targets that correspond to the skills that students are expected to know and be able to do by the time of graduation [1].

A major goal of the Civil Engineering (CE) program at the United Arab Emirates University (UAEU) is to provide students with the necessary preparation in the area of civil and environmental engineering to compete effectively for professional careers in this field and with the motivation for personal and professional growth through lifelong learning. Hence, the educational objectives of the CE program at the UAEU have been formulated following the specifications of ABET Criterion 2. The CE program outcomes that encompass ABET Outcomes A-to-K have in turn been formulated to address the CE educational objectives. The outcomes are threshold statements that describe the general expectations for what should be achieved by all those who graduate from the CE program at the UAEU. The CE program educational objectives and outcomes are presented in Table 2. The assessment of educational objectives is carried out by mapping the A-to-K program outcomes to the relevant educational objectives. This linkage, along with the corresponding relevance weights, is presented in Table 2. Tabulated data shows that each of the educational objectives is linked to three to six program outcomes. This allows for attaining a more reliable measure of the educational objectives through assessment of program outcomes through the application of the proper relevance ratio that expresses the correlation between each outcome and the assessed objective.

Table 2. CE Program Educational Objectives, Outcomes and Corresponding Relevance Levels.

CE Program Educational Objectives	CE Program Outcomes	Relevance Level*
1. Take pride in their profession and have commitment to highest standards of ethical practices, and high level of awareness of social, economical, and environmental issues relevant to the civil engineering profession.	**F**	**5**
	J	**4**
	H	**5**
2. Successfully deal with real life civil engineering problems and achieve practical solutions based on a sound science and engineering knowledge.	**A**	**4**
	C	**4**
	D	**4**
	E	**4**
	H	**4**
	K	**4**
3. Efficiently design, build and/or evaluate a civil engineering system/component to satisfy certain client needs per design specifications and/or interdisciplinary requirements.	**A**	**3**
	B	**4**
	C	**5**
	E	**4**
4. Communicate effectively and use modern engineering tools efficiently in all aspects of professional practices.	**D**	**4**
	G	**5**
	K	**5**
5. Develop and update their knowledge and skills through professional programs and graduate studies to keep up with the rapidly evolving technologies.”	**I**	**5**
	J	**4**
	K	**4**

***** Relevance levels are based on 1 to 5 scale with 5 represents the highest relevance.

III. DEVELOPING COURSE OBJECTIVES AND OUTCOMES TO MEET CE PROGRAM OBJECTIVES AND OUTCOMES

After program educational objectives and outcomes have been formulated for an engineering program in accordance with the ABET requirements, the next step is to identify, for each course, a set of course objectives and outcomes. The objectives and outcomes of each course have to be designed to meet the overall program objectives and outcomes. In addition, course objectives and outcomes have to be measurable in order to be assessed and improved. A course objective is a statement of an observable or measurable student action that serves as evidence of knowledge, skills, and/or attitudes acquired in a course. The statement must include an observable action verb, i.e. explain, calculate, derive, or design to qualify as a learning objective. On the other hand, a course outcome is a statement of non-observable actions such as knowledge, skills, learning, understanding attitudes that the students who complete a course are expected to acquire. Understanding, for instance, cannot be directly observed; the student must do something observable to demonstrate his/her understanding. The outcomes anticipated in each course should map onto or be identical to one or more program outcomes.

Identification and assessment of the outcomes of the Structural Steel Design (CIVL 417) course is the main focus of this paper. The course educational outcomes can be summarized as:

O1. Select the most suitable structural system for a steel roof truss or a steel floor system.
O2. Identify and compute the design loads on a typical steel building.
O3. Identify the different failure modes of steel tension members, and compute the design strength of such members.
O4.Select the least weight section size for a steel tension member.
O5. Identify the different failure modes of steel columns or compression members, and compute the design strength of such members.
O6. Select the most suitable section shape and size for a steel compression member according to a specific design criterion.
O7. Identify the different failure modes of steel beams subjected to simple or double bending, and compute the design strength of such members.
O8. Select the most suitable section shape and size for a steel beam according to a specific design criterion.
O9. Identify the different failure modes of bolted connections for tension or compression members, and determine the design strength of such connections.
O10. Identify the different failure modes of welded connections for tension or compression members, and determine the design strength of such connections.
O11. Design bolted or welded connection for tension or compression members.
O12. Identify the various types of bolted connections in steel construction, and design simple shear (beam-to-girder or girder-to-column) bolted connections.
O13. Utilize advanced computer software packages for the analysis and design of steel structures.
O14. Express their ideas more effectively during classroom discussions.

The course educational objectives and their relation to its outcomes are shown in Table 3. Shown also in the same table are the relevant CE program outcomes along with the relevance levels between the course and the program outcomes.

Table 3. Structural Steel Design Course Objectives and Outcomes and relevance to CE Program Outcomes

Course Objectives	Course Outcome	Relevant CE Program Outcomes	Relevance Level*
1. To introduce the students to the different design philosophies for steel structures and the basic steps in the design process.	O1	**A, E**	**5, 5**
	O2	**A, E**	**5, 5**
2. To introduce the students to the design of the main steel members of a steel structure according to the AISC/LRFD specifications	O3	**A, E**	**5, 5**
	O4	**C**	**4**
	O5	**A, E**	**5, 5**
	O6	**C**	**4**
	O7	**A, E**	**5, 5**
	O8	**C**	**4**
3. To help students understand the behavior and design of direct shear connections.	O9	**A, E**	**5, 5**
	O10	**A, E**	**5, 5**
	O11	**C**	**4**
4. To help students understand the behavior and design of different steel connections.	O12	**C, E**	**4, 5**
5. To develop students' computer skills in designing steel structures.	O13	**C, E, K**	**4, 5, 2**
6. To help improve the verbal communication skills of the students.	O14	**G**	**1**

***** Based on 1 to 5 scale with 5 represents the highest relevance. .

IV. ASSESSMENT OF COURSE OUTCOMES

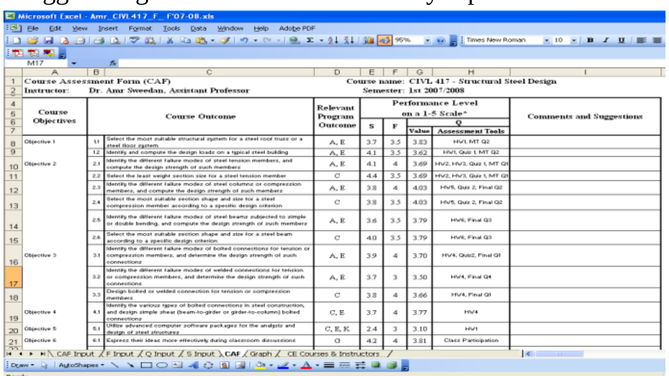
The evaluations conducted during an accreditation cycle require that "each program must show evidence of actions to improve the program. These actions should be based on available information, such as results from Criteria 2 (educational objectives) and 3 (program outcomes) processes". Improving the program starts by improving the course objectives and outcomes. Accordingly, the tools utilized in the assessment of course outcomes are based on student learning and faculty performance. These tools can be a combination of the following:

A. Direct Tools: Homework assignments; Quizzes; Exams; Class participation.

B. Indirect Tools: "Student Assessment of Course" survey; Student's online course assessment; Instructor's teaching performance evaluation (by students).

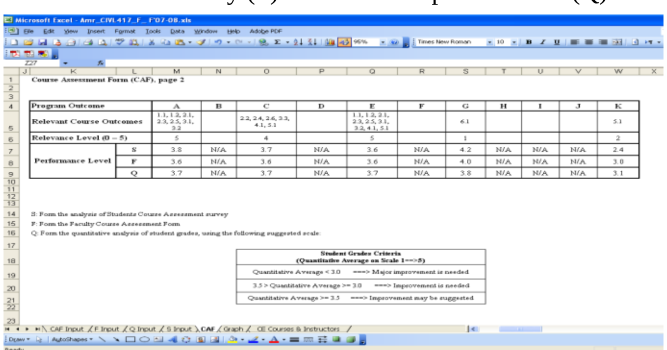
V. ANALYSIS AND RESULTS

The tools to evaluate student-learning quality include: homework assignments and quiz 35% of the overall grade, midterm exam 25%, and final exam 35% of the overall class grade. Students' participation and oral presentation count 5% of the overall class grade. Figures 1 and 2 show the performance assessment sample of students taking Structural Steel Design (CIVL 417). Figure 3 indicate that the performance criteria were net in this course for the Fall Semester of 2007. Figure 4 shows the performance criterion for each of the course contents/outcomes was met. Students didn't show very good level of satisfaction in utilizing computer software in analyzing structural systems. It was recommended to put more emphasis on the significance of this item by assigning a separate assignment that focuses on that goal rather than being a part of a bigger assignment that deals with many aspects.


Course Assessment Form (CAF) — Course name: CIVL 417 - Structural Steel Design
Instructor: Dr. Amr Sweedan, Assistant Professor — Semester: 1st 2007/2008

Course Objectives		Course Outcome	Relevant Program Outcome	S	F	Q Value	Q Assessment Tools	Comments and Suggestions
Objective 1	1.1	Select the most suitable structural system for a steel roof truss or a steel floor system	A, E	3.7	3.5	3.83	HW1, MT Q2	
	1.2	Identify and compute the design loads on a typical steel building	A, E	4.1	3.5	3.62	HW1, Quiz 1, MT Q2	
Objective 2	2.1	Identify the different failure modes of steel tension members, and compute the design strength of such members	A, E	4.1	4	3.69	HW2, HW3, Quiz 1, MT Q1	
	2.2	Select the least weight section size for a steel tension member	C	4.4	3.5	3.69	HW2, HW3, Quiz 1, MT Q1	
	2.3	Identify the different failure modes of steel columns or compression members, and compute the design strength of such members	A, E	3.8	4	4.03	HW5, Quiz 2, Final Q2	
	2.4	Select the most suitable section shape and size for a steel compression member according to a specific design criterion	C	3.8	3.5	4.03	HW5, Quiz 2, Final Q2	
	2.5	Identify the different failure modes of steel beams subjected to simple or double bending, and compute the design strength of such members	A, E	3.6	3.5	3.79	HW6, Final Q3	
	2.6	Select the most suitable section shape and size for a steel beam according to a specific design criterion	C	4.0	3.5	3.79	HW6, Final Q3	
Objective 3	3.1	Identify the different failure modes of bolted connections for tension or compression members, and determine the design strength of such connections	A, E	3.9	4	3.70	HW4, Quiz2, Final Q1	
	3.2	Identify the different failure modes of welded connections for tension or compression members, and determine the design strength of such connections	A, E	3.7	3	3.50	HW4, Final Q4	
	3.3	Design bolted or welded connection for tension or compression members	C	3.8	4	3.66	HW4, Final Q1	
Objective 4	4.1	Identify the various types of bolted connections in steel construction, and design simple shear (beam-to-girder or girder-to-column) bolted connections	C, E	3.7	4	3.77	HW4	
Objective 5	5.1	Utilize advanced computer software packages for the analysis and design of steel structures	C, E, K	2.4	3	3.10	HW1	
Objective 6	6.1	Express their ideas more effectively during classroom discussions	G	4.2	4	3.81	Class Participation	

Fig. 1. Performance levels of the course by the faculty (F), student's survey (S) and Student's performance (Q)


Course Assessment Form (CAF), page 2

Program Outcome		A	B	C	D	E	F	G	H	I	J	K
Relevant Course Outcomes		1.1, 1.2, 2.1, 2.3, 2.5, 3.1, 3.2		2.2, 2.4, 2.6, 3.3, 4.1, 5.1		1.1, 1.2, 2.1, 2.3, 2.5, 3.1, 3.2, 4.1, 5.1		6.1				5.1
Relevance Level (0 – 5)		5		4		5		1				2
Performance Level	S	3.8	N/A	3.7	N/A	3.6	N/A	4.2	N/A	N/A	N/A	2.4
	F	3.6	N/A	3.6	N/A	3.6	N/A	4.0	N/A	N/A	N/A	3.0
	Q	3.7	N/A	3.7	N/A	3.7	N/A	3.8	N/A	N/A	N/A	3.1

S: Form the analysis of Students Course Assessment survey
F: Form the Faculty Course Assessment Form
Q: Form the quantitative analysis of student grades, using the following suggested scale:

Student Grades Criteria (Quantitative Average on Scale 1==>5)
Quantitative Average < 3.0 ===> Major improvement is needed
3.5 > Quantitative Average >= 3.0 ===> Improvement is needed
Quantitative Average >= 3.5 ===> Improvement may be suggested

Fig. 2. Performance assessment of the program-outcome related course contents outcomes

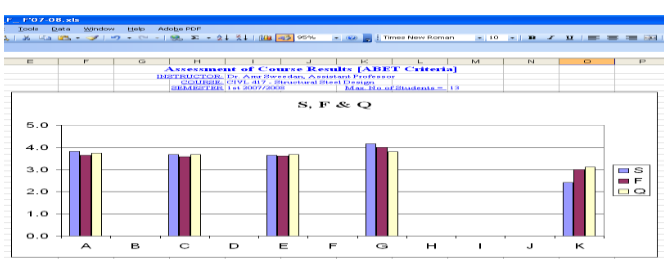


Fig. 3. Assessment of course results

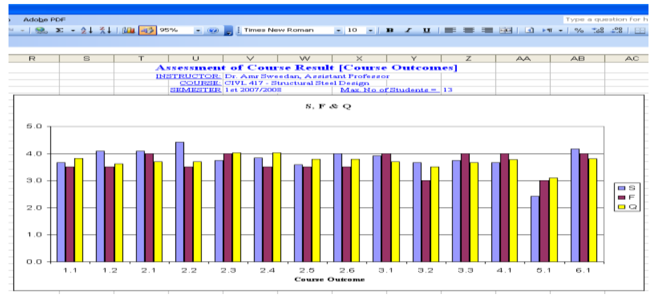


Fig. 4. Assessment of the course outcomes

VI. CONCLUSIONS

This paper describes, in details, the development of assessment tools for outcome-based engineering courses. Development of course educational objectives and outcomes that are consistent with the CE program objective and outcomes is described. Mapping of the course contents to ABET criteria (A-to-K) and assessment tools are also discussed. Excel spreadsheet is developed to enable performing the assessment of course outcomes. The procedure to implement the criteria in class teaching and assessment tool was also discussed in details. Sample data collected from Structural Steel Design course, offered in the department of Civil and Environmental Engineering at UAEU through the Fall 2007 indicated that the student learning performance was improved in the process. The data indicate that the development of assessment tool for outcome-based engineering courses is working in the positive direction. More data need to be collected to enhance and improve the proposed assessment tools on the long-term. This would allow for analyzing the tools statistically in order to improve student-learning performance and enhance instructor-teaching performance.

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TRANSFORMING AN ENGINEERING MANAGEMENT COURSE TO ONLINE DELIVERY

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Abstract — Engineering courses are traditionally delivered face-to-face supplemented with blended delivery using learning management systems. Increasingly attractive is the promise that full on-line deliveries broaden the reach of engineering/management courses, appeal to student convenience and learning preferences, lower pressure on brick and mortar facilities and promote education in general via MOOC platforms.

With initial references to MOOCs dating back to 2008, Stanford University led the way in 2011 by offering three open enrolment, on-line engineering courses covering artificial intelligence, machine learning and databases. From modest beginnings, universities and academic institutes currently offer thousands of courses via Coursera, edX, Edraak and other platforms.

McMaster University's Bachelor of Technology Program has experimented with blended on-line delivery over the last number of years, most recently with two engineering management courses where students report general satisfaction with distance learning modalities, but not without reservations. A course design team comprised of pedagogical, digital and subject matter experts are transforming a face-to-face entrepreneurship course to full on-line delivery utilizing the range of best distance education practices. Such practices include creation of high production value asynchronous media content, frequent automated tests and quizzes, synchronous bi-weekly tutorials, remote group work including business case/plan presentations and third party mid-term and final exam proctoring. The presented paper focuses on methods and means for enhancing and transitioning traditional courses to engaging, totally on-line learning environments.

Keywords — blended, face-to-face, hybrid, learning ecosystem, learning outcomes, MOOCs, online delivery, teaching/learning modalities

I. BACKGROUND

Traditional face-to-face classroom course delivery, engineering and otherwise, is increasingly giving way to potentially disruptive, paradigm defining pedagogical modalities variously referred to as: blended learning, hybrid teaching, synchronous online instruction, asynchronous delivery, computer mediated distance education, among others. As these terms can be interpreted and applied in many different ways, those entering into a discussion about online delivery need to seek definitional clarity.

As a reflection of technological advances, college/university budgetary pressures, brand extension, growth potential via MOOCs, and democratization of education, many institutions have adopted various online pedagogical paradigms. From a student perspective, online delivery provides many advantages including: flexibility, convenience, cost (free MOOC) and the ability to present credentials from world renowned schools.

Regardless of driver, economic, sociological, or otherwise, it would appear face-to-face (F2F) classroom delivery is competing with alternatives that theoretically promise to achieve prescribed learning objectives, albeit in a different format and potentially, in a more cost effective manner.

Globally, and within Ontario, online learning represents one of the fastest growing post-secondary educational trends. In 2011, Ontario post-secondary institutions offered online delivery for over 20,000 courses, 780 programs, translating into almost 500,000 course registrations. Recently, the Ontario government committed $42M over three years to develop courses, improve instruction, and create support hubs aimed at increasing access to high quality education through a single Center of Excellence for Online Learning [1, 2].

In January 2014, the Ministry of Training, Colleges and Universities launched Ontario's Online Initiative (OOI) inviting post-secondary institutes to submit proposals for the development and delivery of online courses with provision for transferability of credits between participating institutions to avoid duplication [2].

As a continuation of McMaster's commitment to online education through a range of faculties including psychology, sciences, health sciences and engineering, the university submitted multiple OOI proposals spearheaded by various Schools.

Complimentary to the university's response, the Bachelor of Technology Program (B.Tech.), submitted a proposal to convert a Technological Entrepreneurship course to full online status. It should be noted that this program has been delivering an increasing number of online lectures/classes over the past number of years. In April 2014, B.Tech. was awarded an OOI grant to transition a blended delivery course to full online by January 2015.

The objective of this paper is to discuss B.Tech.'s OOI application process and share the course development experience (challenges, best practices, caveats).

II. ONLINE DELIVERY

The Province's proposed Center of Excellence for Online Learning intends to give students access to high-quality, transferable online courses/credits. With a launch window of fall 2015, the Center of Excellence is expected to promote the province as a leader in e-learning at a world-class level. Such initiatives ensure that Ontario continues to be viewed as being in the vanguard of pedagogical innovation.

The notion of delivering courses online as a pedagogical alternative sparks considerable discussion, sometimes heated, as that relates to the pro's and con's of such a modality. Arguments/concerns by stakeholder follow:

Institutional

- Defense of standards/academic integrity
- Online development/ongoing costs for maintaining and updating course materials
- Course ownership

Faculty

- Achieving learning outcomes online versus F2F (hands-on skills, labs, critical thinking, design, argument, teamwork, presentation)
- Instructor-student engagement/relationship
- Student assessment/evaluation
- Acquiring skills to teach online
- Technological limitations
- Job security

Students

- Quality of learning believed to be higher F2F
- Challenges of group work
- Weak attachment to course, instructor and institution

Lining up arguments for not proceeding with online delivery is a relatively simple task as a constellation of concerns can easily be obtained on various blogs/discussion forums and papers found on the internet. Despite the listed concerns, McMaster has made the decision to wade into the online waters on a program by program, course by course voluntary basis.

III. OOI APPLICATION PROCESS

The process of completing the OOI application required addressing a number of factors including:

- Course purposes/learning outcomes
- Course pedagogy suitable for online delivery
- Enrollment/scalability
- Budget
- Assurance of credit transfer
- Level (foundational vs. advanced)
- Applicant school online experience
- Applicant online pedagogical competence

It should be noted that the university's OOI initiative was co-ordinated by the McMaster Institute for Innovation and Excellence in Teaching and Learning (MIIETL) through various departments/schools expressing interest in online teaching. The OOI grant provided B.Tech. the opportunity to pursue development work with required resourcing. Accordingly, a design team comprised of a subject matter expert (SME), instructional designer and a digital media specialist was tasked with implementing the immediate project. The proposed team approach aligns with advice provided by instructional designer, Dean Caplan: "In the ideal world, instructional media developers are included in the course development process from the beginning, to consult with and advise course team members on development-related topics as they arise" [3]. OOI funding went some distance in providing resources to create an optimal course development model, including SME release time.

IV. DESIGN PRECEPTS

To ensure effective course delivery, transition from F2F to online requires careful planning and preparation. In a much cited paper, Chickering and Gamson (1987) provide a selection of techniques for teaching undergraduates in a F2F format including [4]:

1. Encourages student-faculty contact
2. Catalyzes co-operation between students
3. Promotes active learning
4. Provides timely, detailed feedback
5. Emphasizes time on task
6. Communicates high expectations
7. Respects diverse talents and ways of learning

While the aforementioned observations were targeted for undergraduate learning, these same principles can be generalized to graduate (masters and Ph.D.) level studies. These principles are as relevant today as when first advanced over 25 years ago. Students benefit from institution and peer contact, learn better when doing, proceed with greater confidence when advised they are on the right track with encouragement to aim higher, think about the material on a regular basis particularly between class sessions, and are permitted to experience knowledge acquisition based on personal learning styles, within limits.

On the other hand, instructors offering online materials must think through each of the seven items discussed above and consider student learning rather than assuming that knowledge acquisition occurs by populating a learning management system (LMS).

V. PREPARING TO TRANSITION

Based on the development of the Technological Entrepreneurship course, a number of identifiable steps were set out (Figure 1).

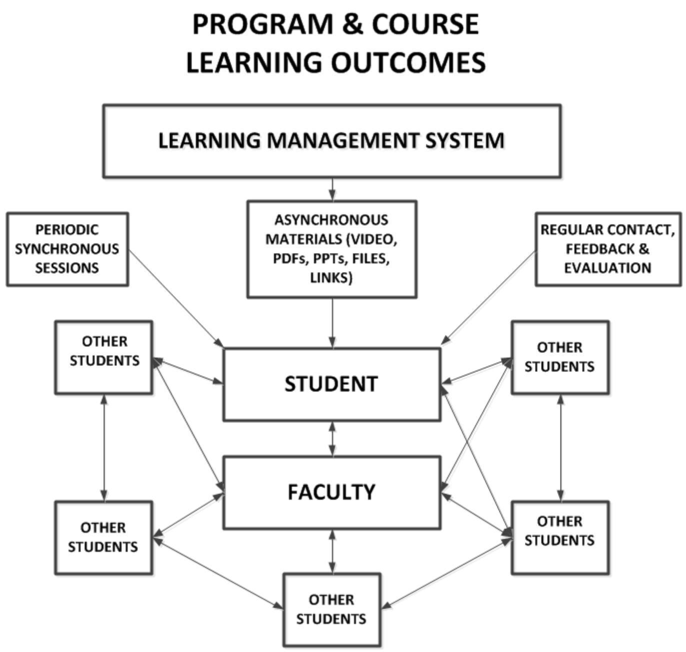

Figure 1: Student Centric Learning Ecosystem

The transition procedure can be summarized with the following:

A. Program and Course Learning Outcomes

In preparation for an online course, arguably the most important activities to be completed involve an early overall review of program objectives followed by an analysis of the course learning outcomes (total of 9 for this course). Both tasks are critical in establishing a framework for all subsequent activities. It should be noted that all course materials and activities must mapped, in varying degrees, onto learning outcomes. Figure 2 illustrates two articulated behaviourally stated learning outcomes.

Entrepreneurship OOI Project Learning Outcomes by Week		
Week 1 (E'ship)	**E's state of mind relative to 'yees/mgrs.**	**Role of E in growing, healthy economy**
Produced Video (E True, Obstacles, Opp'y Finding	✓	✓
Supplemental Materials (infographic, pdfs, ppts)	✓	
Vid of Week (60 Minutes, youtube, CNBC, DD)	✓	✓
Weekly activity (case, simulation, game, o/s)	✓	
WOW (inspiring link, vid, product, statistic, event)	✓	✓

Figure 2: Learning Outcomes by Week

B. Asynchronous/Synchronous Balance

Although full online implies a reduction of student contact, courses can make provision for periodic synchronous sessions. Converting a conventional classroom to online demands that students review materials prior to a pre-scheduled online meeting (flipped classroom). Such synchronous practice permits the instructor/tutor to cover problems, consider cases, deal with project/assignment issues, and undertake activities as a matter of achieving learning outcomes. Time on task can actually increase in an online environment.

C. Student Assessment

For online modality, assessing students' progress and developed skills requires the use of potentially different evaluative methods for tests, quizzes, assignments, projects, and presentations. Mid-terms and finals can handled in a number of different ways including: being conducted on campus, engaging online testing services or using test centers. Utilizing publisher electronic test bank questions, the LMS can administer weekly quizzes by: creating a randomized/individualized test, setting time boundaries for test taking, evaluating the submission, providing correct answers and administering grades. Assignments and projects can come in via LMS dropbox and operating in a 2 computer monitor environment permits the evaluator the ability to view the submission on one screen while providing rubric comments on another. Assignment/project feedback (including audio) is easily handled by the LMS with grades automatically entered into the gradebook. Presentations can be more difficult online as replicating the F2F anxiousness/energy represents something of a challenge.

It is worth mentioning that the literature related to online peer evaluation can be characterized as mixed at best. SMEs should think through the advantages and disadvantages of proceeding with this type of evaluation.

D. Weekly LMS Structure

Figure 2 also illustrates the LMS structure adopted within the Technological Entrepreneurship course. Students are presented with university produced, high production value videos, supplementary downloads, weekly activities for synchronous sessions and some type of inspiring topic related to the week's objectives.

E. Student Engagement

The instructor and design team must remain mindful that the student starts from a position of geographical and psychic isolation in an online environment. A sense of participation, inclusion and community must be created via the tools available. Discussion boards, prompt email responses, skype sessions, synchronous classes, additional on-campus meetings can all serve to minimize students' sense of isolation to the course, instructor and institution.

VI. SME CONTRIBUTION

Table 1 provides an estimate of the time commitment needed on the part of the SME. The SME must appreciate that all materials must be available in digital/electronic format implying that all learning documents must be digitized. Time should also be budgeted for instruction on how to teach online. Some SMEs may also need voice coaching to improve video/audio presentations.

Course Plan (Hr/Wk)*	Actions
Examining/consolidating web site materials (2)	• Improve, optimize, update & organize course materials
Pedagogical planning with MIIETL staff (2)	• Discussing ways & means of achieving learning objectives
Writing video scripts (5)	• Editing/re-editing video scripts
MIIETL meetings (2)	• Standing weekly meeting
Video/audio recording & revisions (1)	• Collaborating with digital expert for video/voice overs
Repackaging new course materials (2)	• Materials converted into McMaster branded format
Review course materials (2)	• Finalizing weekly LMS presentation

Table 1: Planning for Transition

* As per table 1, total SME commitment with all learning materials previously digitized was 208 hours. No estimates are included for the balance of the design team.

VII. LESSONS LEARNED

Professors delivering courses online can anticipate that they will be placing themselves on a learning curve. Be poised for technical computer challenges particularly on the student side (logging in, remaining online, audio problems), weaknesses within the synchronous delivery tools (audio, bringing powerpoints to screen, file sharing), determining whether learning actually occurred, and assessing student attitudes toward online learning (use www.surveymonkey).

Moving a course from F2F to online requires a commitment on the part of the SME and the design team as the group is embarking on what could potentially amount to a year long journey.

Future online developers should keep in mind the following:

1. Starting with a well established/developed course
2. Storyboarding and writing scripts
3. Maintaining a transition schedule with a view to completing a single course within 6-8 months followed by continuous update/improvement
4. Committing to a weekly planning meeting with the implementation team
5. Being sufficiently flexible to evolve materials as a reflection of what works and what needs refinement
6. SME should acquaint self with best online teaching practices [5]

VIII. DISCUSSION & CONCLUSIONS

Many administrators are anxious to proceed with online delivery for a number of reasons. Those same administrators are often of the initial opinion that transitioning to online simply involves "copying" over materials from one LMS shell to another and then "talking" online using synchronous delivery tools. The move to online requires a complete reconsideration as to the efficacy of what can genuinely be achieved within a decidedly asynchronous teaching environment where instructor and pupil may never meet face-to-face. Within the flipped online classroom, responsibilities for teaching and learning are altered to the extent that faculty must think through what works and that which demands reconsideration while the student needs to "come to class" prepared to discuss, argue and problem solve.

Online classes represent something of a new frontier for the Bachelor of Technology Program and McMaster University in general. However, many schools have been delivering online for some length of time while others are making an initial commitment to this modality. For benchmarking visits, consider: Athabasca (circa 1985), Memorial University (1994), U. of Toronto, Waterloo, and U. of Ottawa.

Round 1 of OOI funding is complete with a second wave of funding anticipated for 2015. Keep in mind some of the points within this paper and be poised with an application and a plan so that an 'ideal' implementation can proceed smoothly.

ACKNOWLEDGEMENTS

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Development of Ethics Assessment Strategy for Senior Undergraduate Engineering Physics Course

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***Abstract*–Assessment of ethics as a graduate attribute can be a challenging but thought-provoking process. This paper presents our experience in designing and implementing pilot ethics modules in one Engineering Physics course (Introduction to Energy Systems), where ethical dimension is a key part of sustainability education targeted in these courses. These interactive modules actively utilised peer learning and individual reflections. A review of student responses during modules and final exam provided key insight to how learners made sense of engineering ethics, as well as skills and barriers that require attention in the future modules. We hope that the set of questions and list of learning activities generated from this exploratory process will stimulate discussions that help clarify and deepen what it means to teach and learn ethics attribute as engineering students.**

***Keywords*–engineering ethics; undergraduate education; ethics assessment**

I. Background

Evaluation of engineering graduate attributes is taken as an opportunity to accelerate the advancement of engineering pedagogy and engineering education research at McMaster University. The purpose of this paper is to share what we have learned from our pilot activities on engineering ethics education in the Introduction to Energy Systems course (EP3ES3), in order to stimulate a discussion among colleagues that would help further improve our theory and practice.

Grand challenges facing this generation have prompted increasing attention to engineering and common ethics [1, 2]. Particularly, multiple approaches to defining engineering ethics have emerged [3]. For the purposes of this paper, we highlight the approach to engineering ethics as defined by the profession, in which a profession is defined as *"a number of individuals in the same occupation voluntarily organized to earn a living by openly serving a certain moral ideal in a morally-permissible way beyond what law, market, and morality would otherwise require"* [3]. This closely represents the view that undergirds the proactive nature of students' intended learning outcomes.

Namely for EP3ES3, the learning objectives were prioritised by drawing from internal documents (e.g. Faculty's work on graduate attribute indicators, sustainability competencies, existing course materials and approaches to engineering ethics) and faculty input (e.g. for learner analysis). Our experience with a previous pilot in fourth year Energy Systems course was also critical, during which students sought practical skills in fulfilling their responsibility to the public. With the aim of equipping third year students to be more apt in integrating ethics competencies in their final year technical inquiry projects, the learning objectives were grouped into four categories (Table 1):

Table I. Initial Learning Outcome Categories

Problem analysis	Professional identity	Process management	Behavioural attitude
Define and situate ethical issues, critically evaluate arguments and evidence	*Articulate engineer role and responsibility in relation to public, other professions or stakeholders*	*Develop standards for ethical decisions and process, negotiate and facilitate decision making processes*	*Acknowledge and respond with fairness and transparency to ambiguity, complexity and uncertainties*

II. Design and Delivery of Ethics Modules

A series of three 50-minute modules were designed. These were delivered to 60 students from mainly Engineering Physics and Civil Engineering departments, in their 3rd to 4th academic year. In order to avoid a reductionist approach to solving ethical problems, we had to make our views explicit to students, allow students to arrive at their own conclusions, and provide immediate feedback in order to co-construct ways of organising, making sense of, and evaluating student output. Thus, the modules involved a changing balance between large group, small group, and individual tasks. The overview of main module activities and exam are described below, with the group size indicating the setup of tables in our flexible classroom.

A. *Module 1: In groups of 10-15*

The module aimed to identify impact of engineering in complex social phenomena, and draw on the collective knowledge base to broaden understanding of social impact of engineering. After large group presentation and discussion, each group submitted brainstorm lists and conceptual organisation work.

B. *Module 2: In groups of 4-6*

The goal was to have students critically evaluate and develop arguments on engineering ethics case example, and visually depict how the engineering profession is situated in local context. After large group discussion, students individually submitted their 5 personal principles for ensuring ethically sound decisions in their practice.

C. *Module 3: Walking in pairs, three large workstations*

Students were to derive listening skills from the experience of empathy in communication, and develop facilitation methods through an exercise that requires facilitation and negotiation. After reviewing results from each workstation, students individually submitted their top 7 take-away lessons from the ethics series.

D. *Final Exam: 1 mandatory question and one choice of two*

The goal was to demonstrate students' level of clarity, depth of original thought, synthesis, actionable integration and disposition in developing and implementing competencies that constitute engineering ethics. The mandatory question focused not on 'what is engineering ethics' (question of philosophical debate), but rather 'what does it mean to *be* an ethical engineer in the 21st century context?' Students named and described principles of their choice, and explained their plans on putting these principles in action.

III. STUDENT LEARNING

Student submissions (from modules and exam) and observation notes by instructional team (which included informal feedback from students) provided the data for our preliminary analysis on students' learning. This paper focuses on the data from second individual submissions, where students described the top 7 things they were each taking away from the ethics module series. Students were familiar with this format of activity from an earlier module. From **53** students who submitted responses, the common emergent themes are outlined below (Figure 1).

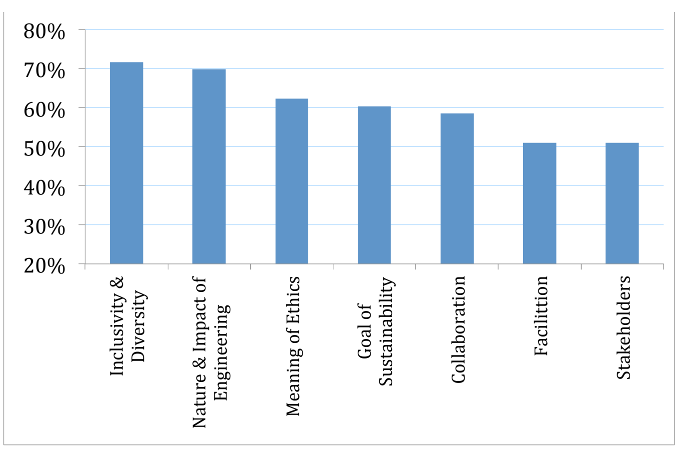

Figure I. Percentage of Students per Common Themes for Acquired Learning

A. *Nature and Impact of Engineering*

Since students' conceptualisation of engineering seemed to tie together other themes highlighted by the students, this category is discussed first. Awareness of the open-ended, complex, multidisciplinary (e.g. 'not just technical') nature of engineering problems was co-presented with the identified need for broad, critical, long-term/short-term, creative thinking. Other important perceptual changes included: awareness of the broad *impact* of engineering; importance of *framework* for problem setting and solving; need for breadth of *facts*; and willingness to acknowledge *uncertainty* and *ambiguity*. Student responses included:

> '*Engineers impact a lot of things, many of these impacts are typically hard to realize. As a result, we need to look at all aspects of every problem.'*
>
> '*Engineering is more than just math/physics. Abstract ideas might actually be really good.'*
>
> '*Not easy to define [problem], many considerations, including scope definition.'*
>
> '*No perfect solutions [are] available, world is a complex space. Need consistent framework.'*

The perceived nature of engineering seemed to justify the role of engineers, their tasks, responsibilities and needed resources or competencies to set and solve problems. This is one of the potential areas for further research.

B. *Inclusivity and Diversity of Input*

Student responses in this category included concepts such as *inclusivity* towards others' opinions and input, *openness* to ideas different from one's own, *withholding judgment* when receiving input, *listening* effectively during interaction, and seeking *diversity* of input for consideration. An important perceptive response was students' recognition of the *value* in others' participation and views, as well as the *skills* to promote inclusivity of diverse input. Examples include:

> *'Most people have something to contribute; [do] not judge other people's ideas immediately.'*
>
> *'Having your voice heard, hearing other people and people's opinions.'*
>
> *'It is important to be empathetic and be a good listener, this will develop stronger relationships.'*

Students recognised that people's input can be subjective (i.e. opinions, views, perspectives). This may indicate an increased level of comfort with ambiguity and subjectivity. Students also recognised the importance of relational and interpersonal dynamics to working with stakeholders.

C. *Meaning of Ethics*

Students made sense of engineering ethics in a wide range of ways, including: nature of ethics in *relation to engineering*; specific qualities of *character* that represent ethical behaviour; the *end goal* or impact of engineering ethics; tasks and *methods* involved in fulfilling ethical responsibilities or standards. Examples include the following:

> '*It's more important to be ethical than technically gifted, although the latter is important.'*
>
> '*Protect the public to the best of one's ability.'*
>
> '*Identify all groups that need to be represented for fairness. Be conscious of how my actions reflect on the engineering profession.'*
>
> '*[Use] good methodology and combining different values will lead to an effective problem statement covering grounds of who, what, how, when.'*
>
> '*Engineers should play a bigger role in raising public awareness of important issues with big implications in society. Public relations and general awareness of society should be part of engineering education. Engineers should learn to become leaders.'*

The diversification of how students made sense of ethical responsibilities of engineers suggested that the class, as a whole, was expanding their vocabulary and knowledge in engineering complexities. The importance and potential of peer learning is again highlighted.

D. Facilitation and Collaboration

Students derived methods and benefits of *facilitation* and *collaboration* in ethical decision-making process (e.g. *'Roles in meetings are essential,' 'Focus discussion on a specific problem statement'*). The value of such methods was in part derived from the nature of problem at hand:

> '*Effective communication is hard to facilitate between groups (missing framework). There are many tools for effective discussions.'*
>
> *'The solution is not always clear, collaborate!'*
>
> '*Difficulty and organisation necessary in steps toward solution.'*

The attention paid to the methods and expected results suggested that students were able to anticipate challenges and describe the complex nature of the decision making process. The recognition of available resources and the difficulty of managing the process alluded to the possibility of stimulating lifelong learning through the module experience.

IV. Continuous Improvement

Several questions were asked to evaluate the effectiveness of the modules and assessment strategy. The first level of evaluation critiqued *fairness* and *alignment* in the design of assessment: "Did the assessment methodology ask for and collect the kind of information sought? Were the opportunities adequate for student performances to be accurate reflection of their abilities/attributes/learning outcomes? Did the instructional activities align with what was assessed?"

The criteria for student assessment need to be grounded in the theory of learning as it applies to the specific discipline [4]. Thus, the second level of evaluation critiqued the *theoretical grounding* (i.e. constructing robust theory based on both sought and unexpected data [5]) of teaching and learning engineering ethics. "What are/were students' actual abilities? What is their actual development process? Which instructional activities supported such development? How do these fit with the current definition of the topic (i.e. engineering ethics) and its theory of learning, both of which undergird teaching strategies?"

A. Assessment

The data generated from the open-ended, semi-structured individual submission format enabled identification of student interpretation of the learning material. The perceptive data provided links between key concepts that explained engineering ethics, with more diversified interpretations than expected. With the limited number of concepts per person, the class as a whole presented a more complete coverage of instructional topics than expected (alignment of module activities and students' learning).

The brevity of many student responses showed a missed opportunity in demonstrating the clarity and depth of learning, in terms of conceptual understanding, skills development, and integration into practice. This was better addressed in the final exam. Even though the written answers do not display the actual behaviour in professional practice, the convergent thinking and synthesis involved in answering the given prompt are expected to demonstrate students' ability to translate principles behind engineering ethics into action.

Main areas for improvement to be addressed by a combination of assessment methods are as follows:

- Integration with discipline - Assess ethics competencies with tighter integration with disciplinary depth (i.e. case studies, integration in existing engineering inquiry or project reports).
- Critical thinking - Prompt more depth and clarity of reasoning, especially in argument development and evaluation of evidence or reasoning.
- Translation into action – Highlight how students make sense of, and apply, principles of engineering ethics in their academic, professional or extracurricular activities.
- Self-evaluation – Draw attention to the learning process.
- Synthesis of framework – Maximise the value of peer learning and immediate feedback.

B. Learning Theory

The pilot activities in EP3ES3 were valuable for our endeavours in engineering ethics education for two reasons. First, we have a more informed learner analysis – a better understanding of the students' abilities, and the concepts and reasoning they used to make sense of engineering ethics. Secondly, more specific questions were drawn about the connection between experiential learning methods and their impact on student learning, namely for considering new perspectives, values and skills.

Students' conceptualisation of engineer role and responsibility was most evident of how students might interpret and internalise the instructional content on engineering ethics. Without a lecture, there were key messages emerging out of the feedback exchange between the instructional team and students, involving concepts such as informed optimism, agency, fairness, challenging assumptions, and comfort without complete consensus. Nevertheless, students adopted key terminology from the structured prompts and activity descriptions themselves. Given that language and conceptual framework are critical for scaffolding knowledge, we would like to know how we provide tools and make room for students to reach their own conclusions.

It is yet unclear what learning experience or content encouraged students to rethink the nature of engineering (an unexpected outcome). Students worked through bringing clarity to a fuzzy connection of engineering to social phenomena (e.g. single mothers, disability, human trafficking). Students shared their own prior knowledge and experiences to evaluate the existing, and open up to possibilities. Facilitation and group work skills used regularly. Students derived principles and skills from modules activities that insinuated that the 'why' and 'how' questions are, or can be presented as, inseparable (e.g. explaining why they value input from others and asserting the need to facilitate such input).

Answering the feasibility question (i.e. whether one can indeed successfully learn and achieve an outcome) seemed to answer the challenge of commitment (i.e. that one assumes the responsibility and commits to perform it). In other words, developing commitment to the responsibilities as an engineer may require more diversified training in how one would effectively perform those responsibilities in specific settings and processes. Especially where defensiveness or internalised powerlessness are present (e.g. 'cannot do anything besides what is told'), the sense of optimism from concrete examples and practice may be of great benefit – to promoting active translation of engineering ethics principles into action.

Responsibility – an ability to respond to others [6] – was expected to involve complex analytical, relational, and emotional connections to even distant stakeholders as real persons. We would like to investigate how much of students' value for inclusivity was influenced by the short activity on empathy and listening (done in pairs) or by group facilitation exercises where students negotiated for consensus. Both activities involved being responded to, or being heard.

Most of what students learned from the modules demonstrated competencies at the *awareness* level; much potential was identified in building skills to *manage* processes. It should be noted that a number of students also identified the importance of broader participation in society and of leadership – The ability to influence change for the public good can serve both a vision and a challenge for engineering ethics education. Each of the three categories (i.e. awareness, management, direction) involves student abilities that can be demonstrated for assessment. There is an increasing ability to conceptualise, and bring concrete reality to, an ideal (e.g. equity, sustainability). Although the progressive relationship between learning outcomes is a topic of further study, a working framework has been developed to organise and interconnect learning outcomes with instructional strategies (Table 2).

Table 2. Instructional Framework for Engineering Ethics Development

Awareness	Management	Direction
Connecting the individual to the realities engineering ethics with: Foundational concepts, contextual information, theoretical and practical knowledge, skills, attitude and values	*Giving the tools and opportunities to build mastery in processes necessary to achieve the goals of engineering ethics, integrating best practices in e.g. relational, organizational, operational, analytical processes*	*Developing the ability to influence systemic change by accurately perceiving and responding to the changing context, and creating processes that stimulate and facilitate innovation*

There remains a critical need to gain insight into students' learning process, improve instructional responsiveness to the learning process, and develop a robust theory of learning in engineering ethics. This paper concludes with major tasks we would like to address in order to further our theory and practice in engineering ethics education:

- Incorporate pre-test for prior skills (including approaches to ethics problems), knowledge, and values.
- Identify how students interpret or conceptualise ethical dilemmas, engineer role, the context and nature of engineering profession.
- Identify any critical concepts or rhetoric that either facilitate or hinder learning engineering ethics.
- Find ways to challenge assumptions or misconceptions and build on prior learning.

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Implementation and Integration of Phasor Measurement Units in Smart Grid Test Bed

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***Abstract*— This paper presents a phasor measurement unit (PMU) implementation on a hardware-based smart grid test bed at Florida International University. The educational platform was used to investigate theoretical and experimental studies for students to achieve high level of experience in modern time-synchronized power system analysis. Experimental studies were carried out with laboratory based developed PMUs as well as commercial units. Online time-synchronized power flow and transmission line parameter identification experiements were realistically operated as educational case studies.**

***Keywords*—**PMU, PDC, Synchrophasor, Testbed, Smart Grid.

I. INTRODUCTION

Recent catastrophic events have focused attention on resilient and reliable electric grids, which requires governmental and utility concern. Furthermore, rapidly aging electric grid infrastructure can easily fall into a vulnerable situation due to extreme weather events, earthquakes and other deteriorating effects. Therefore, utilities are seeking ways to monitor complete power system in real-time with time-synchronized approach. Accordingly, the number of PMUs deployed by utilities have increased rapidly in the last decade to exploit the benefit of time-synchronized measurements for monitoring, protection and control purposes.

A PMU is commonly referred as a synchrophasor which is one of the most important measurement devices in the power systems. A common time source is used to synchronize the measured voltage and current waveforms. The most accurate and globally available time source is global positioning system (GPS). Actual voltage and current measurements from different parts of the power system are collected with the time signal obtained from a time source, which results in time-stamped measurements. These synchronized phasor packages are sent to the phasor data concentrator (PDC) at the control center.

This paper demonstrates the practical implementation and integration of PMUs and PDC in the smart grid testbed for educational applications of time-synchronized measurements for power systems. The remainder of the paper is organized as follows. Section II presents the hardware infrastructure of smart grid test bed. Section III introduces the PMU basics. Section IV express the implementation and integration of PMUs in the test bed. Section V presents the educational case studies of PMU evaluation and transmission line parameter identification. Finally, the conclusion is provided in section VI.

II. SMART GRID TESTBED HARDWARE

A. High Level Architecture and Features

Smart grid test bed is a state-of-the-art hardware platform with a wide capability to investigate actual power system experimental studies. The integrated hardware based AC/DC hybrid power system provides an environment for replicable tests of scientific theories, tools and technologies. In addition, it has many capabilities to perform experimental research inquiries in addition to educational benefits. It is an excellent basis not only for innovative research ideas, but also for teaching the power system engineering concepts to students at the undergraduate and graduate levels as well as training engineers who are interested in testing new ideas for smart power system operation in a safe laboratory environment. Moreover, it is crucial for electrical and engineering students to experience, involve and interact with smart grid components and its innovative operational aspects.

B. Smart Grid Testbed Platform Specifications

The Smart Grid Testbed Laboratory at Florida International University (FIU) is an integrated hardware based AC/DC hybrid power system which provides a great platform at the laboratory scale to analyze and verify new operation, protection, control and identification techniques in real time and for smart grid applications [1-3].

Figure 1. Experimental Setup

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The reconfigurable laboratory is composed of 4 synchronous generators, a utility connection point, 2 microgrids, transmission lines and load models. More than 200 measurement points and a human machine interface (HMI) is available for virtual system control.

In this paper, the main focus is on the PMU implementation and its educational applications. In addition to the above mentioned platform, new components are involved, such as GPS clock, commercial PMUs, laboratory based PMUs and PDC software. As a compliment [4] is recommended for better understanding of data acquisition procedure and 3-phase measurements.

III. PMU Basics

Before introducing student with actual PMU experiments, it is crucial to give basic knowledge about the phasors.

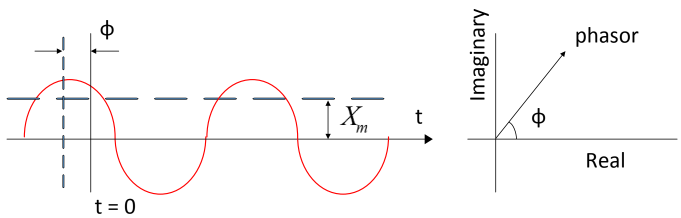

Figure 2. Phasor Representation

The phasor representation of a sine wave is given by:

$$x(t) = X_m \cos(\omega t + \phi) \qquad (1)$$

Where ω is the frequency of signal in radians, φ is the phase angle in radians and X_m is the peak amplitude of the phasor. The complex number representation of equation (1):

$$X = (X_m / \sqrt{2}) e^{j\phi} = (X_m / \sqrt{2}) [\cos \phi + j \sin \phi] \qquad (2)$$

In practice, the signal is corrupted with external noises. Therefore, it is necessary to extract the single principal frequency component by Fourier Transform calculation from a time span, which is known as data window. Since the purpose of this paper is to introduce experimental applications of PMUs, the further theoretical background is not given. The detailed information can be obtained from [5].

IV. Implementation of PMUs at Test Bed

In this section, we introduce PMU implementation at the test bed with two perspectives: commercial and laboratory based PMU implementations.

A. Commercial PMU Implementation

Many vendors around the world are manufacturing PMU units with high quality and high message reporting rates according to synchrophasor standards [4-5]. This test bed owns two commercial PMUs integrated with a PDC and real-time automation controller setup.

A PMU enables one to capture time synchronized measurements such as frequency, phase angle and amplitude of the voltage and current phasors. Moreover, the obtained measurements can be utilized to provide logical feedback to power system field equipment such as, automation controllers (RTAC), programmable logic controller (PLC) and embedded controllers. RTAC supports many industrial protocols such as synchrophasor protocol (C37.118), fast message protocol (SEL), and MODBUS. A PLC is used to control the generator governor emulator frequency driver and circuit breakers of the load models. An embedded controller is used to control an inverter of the flexible ac transmission system (FACTS). The commercial PMU setup is illustrated in Figure 3.

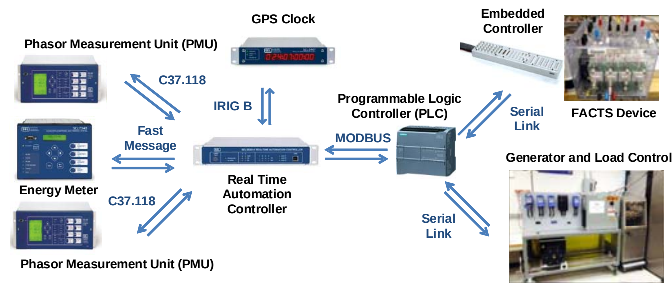

Figure 3. PMU and PLC Setup

B. Laboratory Based PMU Implementation

In order to implement a practical PMU, several high precision components need to operate simultaneously. In this section, we introduce the hardware platform which provides this collaboration. The implemented PMU hardware platform has the structure shown in Figure 4.

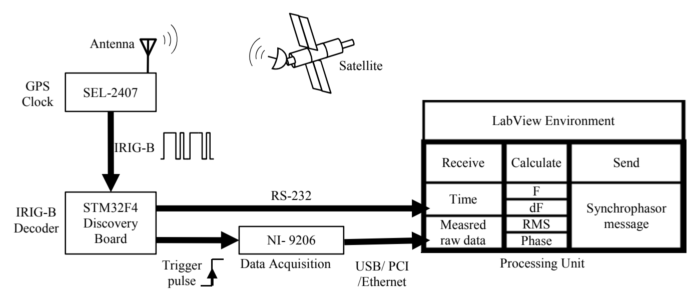

Figure 4. PMU Structure Block Diagram

1) GPS Clock

The precise time source for PMU applications is provided by a GPS clock. It receives the Universal Time Clock (UTC) information from 24 available satellites around the earth and converts it into Inter Range Instrumentation Group (IRIG). IRIG is a standard and accurate time format with different precision and accuracies. This one, which is recommended by synchrophasor standards [6], [7] is IRIG-B and it is defined in IRIG standard 200.04 [5]. This format has the information of seconds, minutes, hours, days and optional control bits with an accuracy of 1 microseconds. It is 1 message per second, containing 100 pulses including 0,1 and flag bits. The experimental setup is using an industrial GPS clock SEL-2407. It is equipped with an antenna located on the roof and has the capability to maintain accurate timing in case the connection to satellite fails.

2) IRIG-B Decoder

Although IRIG-B is accurate and pretty common in industry, it is hard to used with regular processors. As mentioned in [5], it has TTL and Sin wave formats. It is recommended to use TTL levels for digital applications as used in this study. There are two important data sets in each IRIG-B message: 1) UTC 2) Trigger instance.

An embedded IRIG-B decoder was developed to extract this information. It is crucial to transfer this information for the next step accurately and instantly. This is carried out by ARM processor STM32F407 on a Discovery board. Figure 5 demonstrates the process of IRIG-B extraction. It receives the IRIG-B PWM signal, provides the UTC through serial port, and trigger instantly through the GPIO peripheral of the processor.

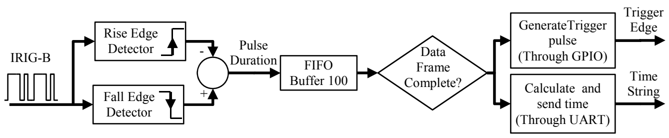

Figure 5. Schematic Diagram of IRIG-B Decoder

3) *Processing Unit*

The processing Unit receives the time and electrical measurements from the inputs, runs the calculations and finds the parameters of the waveforms. Finally, it provides the outputs in synchrophasors format through [6] .

The developed PMU processing unit is in a Labview environment. The main benefits of the Labview environment is hardware/software compatibly and ease of educational aspects.

a) Data Acquisition devision

Plenty of data acquisition modules (DAQs) are available in our platform. We selected NI-9227 which has multi-channel, simultaneous sampling, high voltage, and acceptable performance. The data acquisition unit needs to be accurate with minimum digitizing and offset errors. The sampling frequency should be selected based on the application and coordinated with Nyquist frequency.

b) Calculation division

Measurements captured by DAQ are in the forms of digital waveforms. Standards require f, df/dt, RMS, Phase and positive sequence values of each waveform to be calculated in each data frame of the synchrophasor message per PMU per channel.

c) Communication division

The communication division needs to get the time from IRIG-B decoder and prepare it for the calculation unit. In addition, it has to send the synchrophasor messages to the PDC.

V. Experiments

Learning PMU structure is not enough by itself for future experts, who deal with complex problems. In this section, first we developed several experiments to evaluate the implemented PMU results. Then, we utilized PMUs to extract power system parameters to evaluate online transmission line parameter identification. This is achieved due to the fact that PMUs can provide the synchrophasor information. Traditional approaches are not capable of sending control, protection command or monitoring alarms. Recent solutions combined the above mentioned features in a multifunction device called Phasor Measurement and Control Unit (PMCU).

A. *PMU Evaluation*

One of the criterions to evaluate the accuracy of PMUs is the Total Vector Error (TVE) and it is defined in [7]. It represents the difference between the actual and measured phasors.

$$TVE = \frac{|\vec{V}_{Error}|}{\vec{V}_{Actual}} \times 100\% = \frac{|\vec{V}_{Actual} - \vec{V}_{Measurement}|}{\vec{V}_{Actual}} \times 100\% \qquad (3)$$

TVE express the magnitude, phase and timing error and based on the standards it has to be less than 1%. Figure 6 shows the acceptable margin which PMUs can present their measurements.

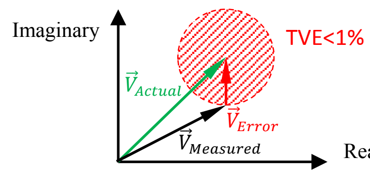

Figure 6. Total Vector Error

The above mentioned experiment was defined to find the TVE for laboratory based PMU validation with respect to commercial PMUs.

B. *Transmission Line Parameter Identification*

In order to find the online impedance value of the transmission line between buses, PMUs can be deployed as shown in Figure 7. A pi-model transmission line emulator was utilized for experiment. Accordingly,

Figure 7 shows the corresponding electrical parameters in each line. The relationship between phasors and line parameters can be obtained as per below equation:

$$\begin{bmatrix} V_s \measuredangle \delta_s \\ I_s \measuredangle \theta_s \end{bmatrix} = \begin{bmatrix} 1 + \frac{YZ}{2} & Z \\ Y\left(1 + \frac{YZ}{4}\right) & 1 + \frac{YZ}{2} \end{bmatrix} \times \begin{bmatrix} V_r \measuredangle \delta_r \\ I_r \measuredangle \theta_r \end{bmatrix} \qquad (4)$$

where $\vec{Z}$ is the line impedance ($\vec{Z} = R + jX$), $\vec{Y}$ is the line admittance ($\vec{Y} = G + jB$) which can be found by:

$$Z = \frac{(V_s \measuredangle \delta_s)^2 - (V_r \measuredangle \delta_r)^2}{(V_r \measuredangle \delta_r)(I_s \measuredangle \theta_s) + (V_s \measuredangle \delta_s)(I_r \measuredangle \theta_r)} \qquad (5)$$

$$Y = 2\,\frac{(I_s \measuredangle \theta_s) - (I_r \measuredangle \theta_r)}{(V_s \measuredangle \delta_s\,) + (V_r \measuredangle \delta_r)} \qquad (6)$$

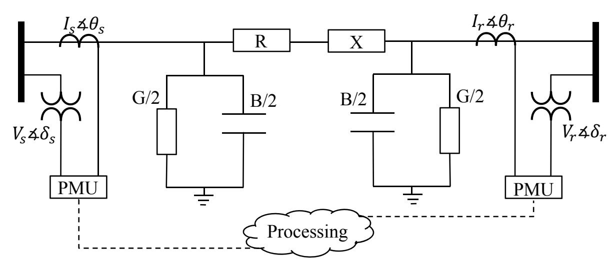

Figure 7. Pi-model of Transmission Line

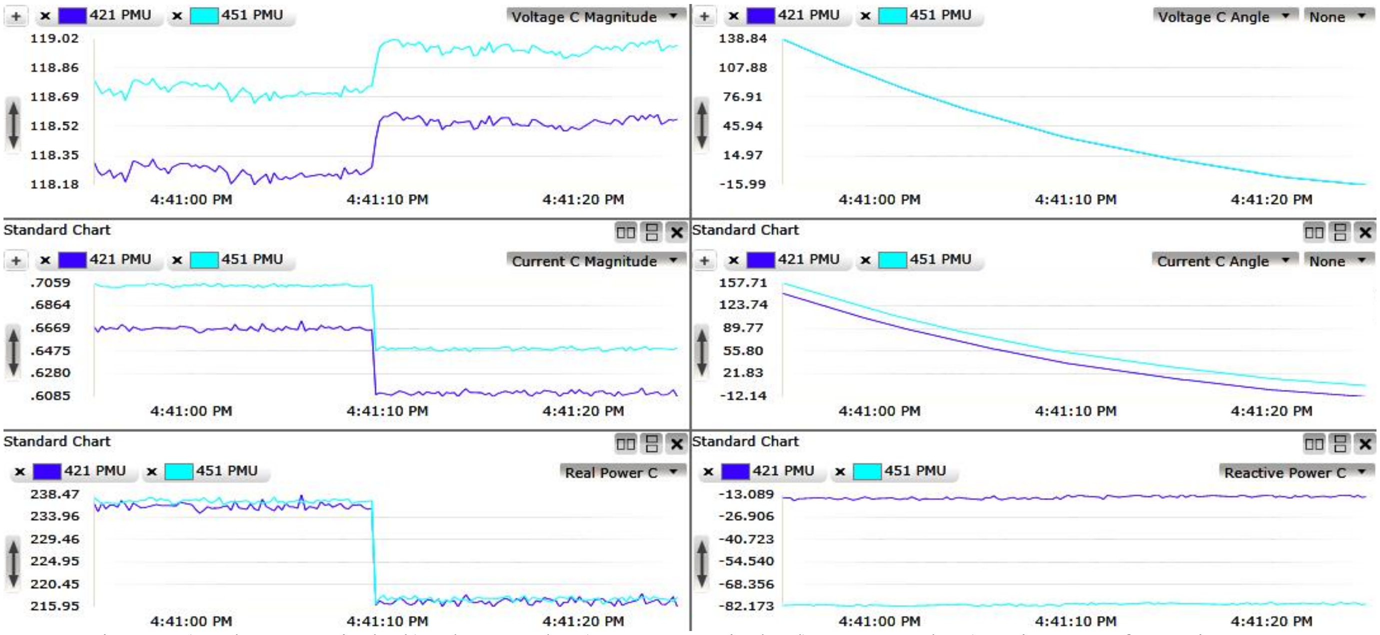

Figure 8. a) Voltage Magnitudes b)Voltage Angles c)Current Magnitudes d)Current Angles e) Active Power f) Reactive Power

Figure 8 illustrates the experimental results for online calculation of the transmission line impedence, where phase C measurements of sending and receiving ends are utilized. PMU 451 is located at the sending end and PMU 421 is located at the receving end of the transmission line. The experiement period is 30 seconds with a rate of 5 synchrophasor messages per second. Initially, a resistive load, which draws approximately 235 Watts was utilized. The load value was switched to 215 Watts at "4:41:09" in order to investigate impedence variation according to loading conditions.

Online calculation of resistance (R), reactance (X), conductance (G) and susceptance (C) are shown in Figure 9and Figure 10.

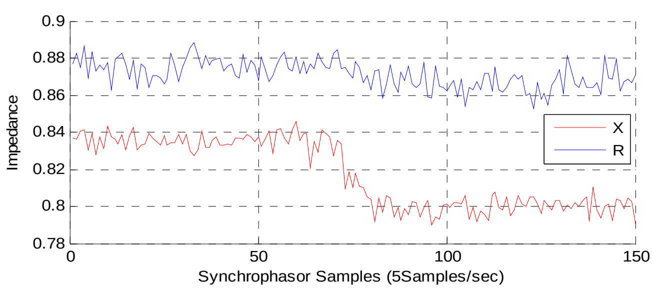

Figure 9. Calculated Resistance and Reactance

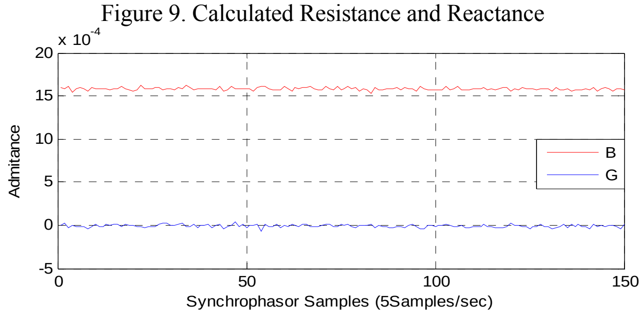

Figure 10. Calculated Susceptance and Conductance

VI. Conclusion

In this paper, a laboratory based and commercial type PMU implementation on a hardware based test bed is explained. PMU evaluation and transmission line parameter identification experiments are demonstrated. It is shown that this educational platform can prepare students to practically learn the concept of time-synchronized measurements in power systems.

Acknowledgment

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Development of Evaluation Equipment of Electric Vehicle for Student Project Team

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***Abstract*—Recently, many universities have various projects as part of engineering design activity by students for engineering education. As one of these activities, Kumamoto University has "solar car project". It is organized by students. The solar car is designed and manufactured by students to participate in the endurance race held in Suzuka Circuit. Through the project, students can experience consistent flow of product design process, not only improvement of their technical skills. Many parameters of solar car should be designed appropriately, for example, dynamic characteristics and effective driving pattern of electric vehicle. Therefore, it is necessary to measure acceleration performance, regeneration performance and power consumption for this purpose. On the other hand, since the solar car team does not have own test course, there is no way to evaluate their car. The car is tested until the race only a few times. Therefore the team has simulated energy consumption by numerical simulation using physical model.**

In this study, the evaluation equipment for solar car was designed for high level production practice for students as part of solar car project. Ttypical evaluation equipment is chassis dynamometer. This is an equipment that measure power and torque by rotating flywheel. In the designing, it is necessary to understand design concept and physical laws. The equipment enables measurement of discharge energy amount and velocity of solar car without driving in test course. The data was compared with the numerical simulation result. The tendency of the actual relationship of discharge energy amount and velocity was same as the simulation result. By improvement of the accuracy of numerical simulation result comparing with the result of the equipment, effective running pattern of the solar car can be evaluated using the equipment without driving in test course.

The equipment makes it possible to student team to experience consistent flow of production carrying out in actual car company, project suggestion, design, manufacturing, test, and implementation.

Keywords*—design education, student project, solar car, chassis dynamometer;

I. INTRODUCTION

In recent years, global environmental concerns, such as global warming, dryness of oil resources and acid rain, are becoming serious problems [1], and the measures against those environmental problems are required in each country. Nowadays, car manufacturers develop new cars for reducing quantity of carbon dioxide emission. For instance, hybrid car which has combined engine system using gasoline engine and electric motor, electric vehicle runs by only electric power and motor, solar car which gets electricity from solar panels, hydrogen engine car using hydrogen gas in substitution for gasoline.

The solar car race using international circuit course came to be played while each company was working on the development of the electric vehicle. Only major car manufacturers participated in the race at first. After that, motors and other necessary parts for solar car had been sold as a kit, technical high school, technical college and university came to participate in the race.

Many universities have been working on solar car project, as a good opportunity to experience of engineering design and manufacturing process. Kumamoto University has participated in the race as activity of solar car project. The solar car project was started up as a student project in 2008 for the purpose of enlightenment of engineering design and manufacturing activity. From the starting of project, machine was designed by graduate students. Though the team was succeeded every year, the vehicle has been designed without certain setting of targeted value and planning of performance, therefore it became gauging design and manufacture. The successive vehicles from 1st to 4th are shown in Fig. 1.

Fig. 1 The participation vehicle from 1st to 4th

From 2012, many undergraduate students also joined, and a professor from car manufacturer joined as a supervisor in 2013. Then design process and production method in actual company have been applied by him. Also project management and instruction to undergraduates came to be requested to graduate students.

However, the solar car project produces the car and participates in the race in very low budget unlike company. Since the development cost is low, the design should be important. And it is necessary to evaluate reliability of the design and analysis to develop the vehicle which can run surely. However, our team did not have the evaluation equipment, place and technique. In this study, we aim to establish a series of manufacturing flows including design, production, evaluation and feedback, which are basics of design and manufacturing process. And we also aim achievement of higher level of engineering design ability of the students in the solar car project.

II. SOLARCAR RACE IN SUZUKA CIRCUIT

Solar car race in Suzuka circuit [2] started in 1992 when the environmental problem, such as air pollution dryness of oil resources, became serious. The clean car which used solar energy was highlighted with expectation as a future dream car, in those days. Major car companies including Honda and Nissan were main participants of the race at first. Solar power came to be used for ordinary house mainly several years later, and became low cost. Then it became easy to use for the solar car race, which is the good practice for students to learn about structure of cars and electric systems. The race became the big race, because participants gather from a big scale, in comparison with other overseas races. Many teams from foreign countries participated in the race, as an approved solar car race of alternative energy cup of FIA first.

The race is divided into various classes by the capacity of equipped solar panels generating system. The race competes for each championship in Suzuka Circuit international racing course (5.807km in total length). In addition, the four hours endurance race is held with machine of the "ENJOY" class, which has the output of solar panels restricted until 480W. The "ENJOY" class is competed for in two classes, one is consists of high school and technical college students younger than 18 years old "ENJOY I", and other is "ENJOY II". In the race, faster running is required with energy management for 4 hours endurance. In this project, we participate in the ENJOY II class. The views of the race are shown in Fig. 2. Our race car in 2013 is shown in Fig. 3.

Fig. 2 View of the race

Fig. 3 General view of our solar car

III. DEVELOPMENT OF THE RACE CAR

The Kumamoto University solar car team [3] is acting with about 26 undergraduates, 4 graduate students and 4 staff of the university including professors and technicians. The graduate students manage the project, and undergraduates are acting as practical members. Not only design ability using technical knowledge in their undergraduate age, but also the project management ability to supervise undergraduate student is requested to the graduate students. On the other hand, the undergraduates can do various experiences to be a full-fledged engineer, while they are learning specialized subjects in the stage.

However, at the start of the project, predecessors had designed and manufactured only by improvement policy without concrete numerical target every year, and evaluated the vehicle by the comparison with previous year result, for instance, reducing aerodynamics resistance, lightening a vehicle weight and so on. A professor from a car manufacturer participated since 2013, and product design method in actual company was applied. Thus, they came to take a procedure of target setting, whole design, and production instead of conventional gauging and improvement design method.

The graduate students set the target with grasping problems of the vehicle and its design of previous year, and then make the plans to achieve the target, and design and development of the vehicle has been done. The development and design divided into four groups, frame and cockpit group, chassis group, cowl group, and electrical equipment group. One graduate student is in charge of each group, and supervises production based on the design to undergraduates. These constitutions of the solar car project team are shown in Fig. 4.

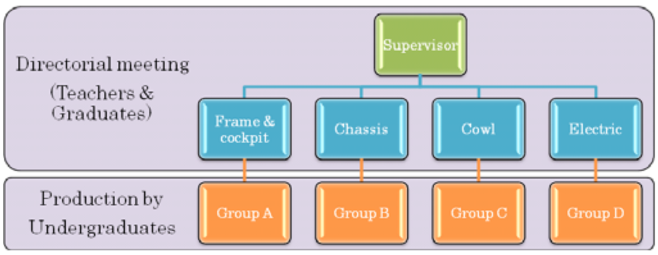

Fig. 4 Team constitution and role

The frame and cockpit group is in charge of the body frame and cockpit, and plan a basic plan of the vehicle. They make a basic plan of the vehicle and the arrangement plan of cockpit.

The chassis group plans the performance of control stability, brake and suspension system. The cowl group aims at the optimization shape of the cowl based on flow analysis, and examines its suitable production method. In addition, the safety performance such as escape method of the driver in emergency has to be designed. The electric equipment group examines the optimum efficiency energy consumption driving pattern in the circuit in consideration of the characteristic of the electric vehicle. And they examine the most suitable placement of solar panels in consideration of its performance. Examples of design by the team constitution described above are shown in Fig. 5 and 6.

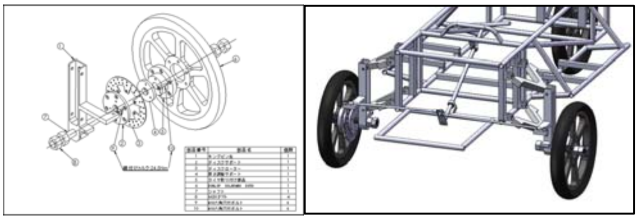

Fig. 5 Design by graduate students

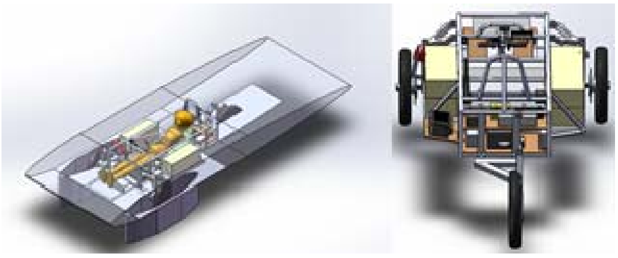

Fig. 6 Design by undergraduates supported by graduates

The students can use the knowledge they learned in university in this activity when designing and manufacturing of the solar car, such as material and machine strength analysis, flow analysis, electrical engineering, electronic circuit, machine design, etc. Though the undergraduates do not have this knowledge necessary for design enough, more effective educational effect is achieved through this project supported by graduate students.

On the other hand, the team did not have own test course, thus, they simply checked performance of the vehicle operation using a little space in the university, and the full-scale test run in borrowed circuit was only one time before the race. There were no test equipment place and technique, even if they simulated and analyzed the performances. Thus, we developed an equipment to perform tests and evaluate the performance. And the results were compared with numerical simulation for validation.

IV. Development of Perfomance Evaluation Equipment and Utilization

We developed an evaluation equipment to test performance of our solar car easily without own test course. It is a good opportunity for students to acquire knowledge of correct engineering ability for design and manufacture.

The equipment uses the principle of the existing chassis dynamometer [4]. The chassis dynamometer provides a similar driving environment on it for test vehicle by adding equivalent inertia mass. The equivalent inertia mass is determined from the following expressions, Kt = Kr.

$$K_t = K_r$$

$$Mr_1^2\omega_0^2 = (I_1 + I_2)\omega_0^2$$

$$I_2 = Mr_1^2 - I_1$$

$$\frac{1}{2}\rho_2 \pi r_2^4 L = Mr_1^2 - I_1$$

$$L = \frac{2Mr_1^2 - 4I_1}{\rho_2 \pi r_2^4}$$

K_t : kinetic energy of translation
K_r : kinetic energy of rotation
M : mass of vehicle
r_1 : radius of roller
ω_0 : angular velocity
I_1 : moment of inertia of roller
I_2 : moment of inertia of weight
ρ_2 : density of weight material
L : thickness of weight

Here, Kt is energy of translational motion calculated from weight of vehicle and driver with velocity, Kr is energy of rotational motion calculated from weight and dimensions of flywheel. In this study, S25C carbon steel was used as the material of weight. The calculated thickness of weight is 370mm for diameter of 250mm. These are set on both of the roller in right and left ends for same value of bending moment.

For the frames, ALFA FRAME(TM) which is aluminum alloy structural material was used. It can be easily assembled. The frames were designed to assure safety factor over 8, by analysis using 3D-CAD and CAE. The designed strength is over 8 of safety factor for acting of both appearance vibration loads.

The equipment has twin roller [5] for ensuring safety, not to fall off the driving wheel. The relations between the frictional force and distance of roller are shown in Fig. 7. The distance of twin roller axles should be decided by coefficient of static friction between rollers and the tire which was measured by static friction test. The test was executed three times for 15N and 30N loads.

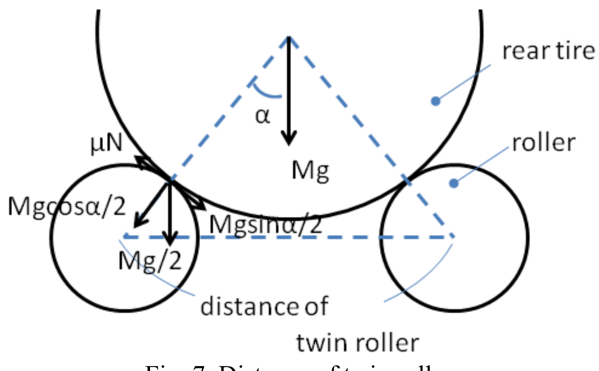

Fig. 7 Distance of twin roller

Fig. 8 shows the results of the friction tests. From the result, maximum coefficient of static friction μ was 0.46. When the distance of axles is 370mm, fall off will occur for μ-value of over 0.80. Therefore this test value is safety, and the distance of axles was decided to 370mm.

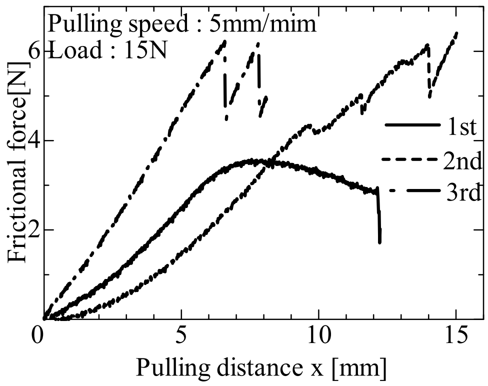

Fig. 8 Static Friction test

The equipment was designed using these test result. Its general view is shown in Fig.9. The size is 700*740*300 (W*L*H).

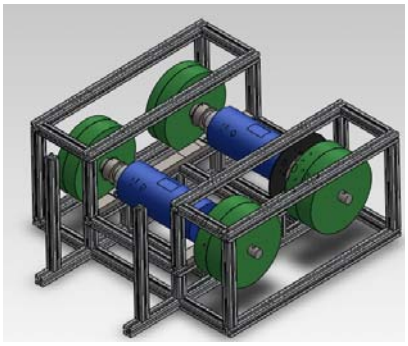

Fig. 9 General view of the evaluation equipment

The bench test is performed using the developed evaluation equipment. The fixation of vehicle on the equipment is shown in Fig. 10. From the bench test result, the tendency of the electric power consumption was same as the numerical simulation result as shown in Fig. 11.

But the amount of the electric energy consumption was 8% high from the simulation result. From these results, it was not greatly different from real run, and it was judged enough to be

Fig. 10 Execution of performance test using the equipment

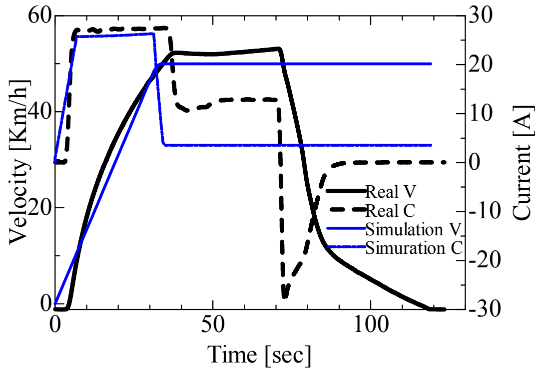

Fig. 11 Comparison result of simulation and real driving

available for a test of vehicle driving. Using this equipment, performance of vehicle can be measured, and running test based on the analysis and those feedbacks become available.

Hence, a series of flows of product design process, design, trial manufacturing, analysis, feedback, as in actual company will be able to be performed. Superior design and manufacturing is enabled, and higher educational effect in this student project is expected. In addition, the student in charge of the equipment design and manufacturing had good opportunity to experience product design process, and his knowledge necessary for product design was reinforced.

V. CONCLUTIONS

The vehicle performance evaluation equipment was completed and became able to easily test solar car which student team designed. Thus, the team is able to perform product design process in the solar car project, which consists of basic design, trial manufacturing, test, evaluation. Before using this equipment, the solar car had been designed based on only forecast and analysis. But now they can evaluate the reliability and quality of their design, and manufacturing quality has been enhanced.

And by using the equipment, certain educational effect to the solar car project was confirmed. In addition, for the student who designed the equipment, high educational effects were confirmed.

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Urban Mega Transit Projects in Capstone Engineering Design Course: Win-Win Educational and Professional Development Strategy

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Abstract - **The Capstone comprehensive engineering design course, required by the Accreditation Board for Engineering and Technology (ABET) in undergraduate engineering programs, provides a unique opportunity to design a real engineering project in an interdisciplinary setting. Successful professional development and academic research programs that have been implemented on the Urban Train heavy rail system in San Juan, Capital of the Commonwealth of Puerto Rico, can be combined with a technology transfer component to make it a win-win strategy in the next generation of engineering students.**

The Professional Development Program between the University of Puerto Rico at Mayagüez and MIT and other public and private universities in the Island and USA that started twenty years ago using the design, construction, operation and maintenance of the first phase of the Urban Train-heavy rail system in Puerto Rico, is an example of initiatives that can be implemented in Capstone design course for the future phases of this heavy rail transit project.

In this paper the experience of planning, designing, constructing and operating the Urban Train having students from engineering and other disciplines in the different stages of the project is described as having a potential for becoming a model for applied university research in the public transportation field and collaboration of universities, public agencies and private companies.

This paper describes the major components of this innovative program which provided a living laboratory for the study and research of rail transit technology as well as a real work experience to university students supervised by practicing professionals. It includes professional development of students of engineering and other disciplines; strengthening research based interdisciplinary multi-modal transportation and land use planning; strengthening the planning and execution of the Urban Train project through "just in time" university based research directly related to the different phases of the train.

Finally, it describes academic procedures on how traditional Capstone engineering design course can be adapted to incorporate new phases of this mega project in collaboration with other engineering program with universities in the United States and Canada.

Keywords – Urban Mega Transit, Capstone Engineering Design Course, Professional Development.

I. Introduction

The Commonwealth of Puerto Rico increased planning and design efforts for a new heavy rail system in the San Juan Metropolitan Area (SJMA). The first phase of this rail system, known as Tren Urbano (Urban Train), consist of 17.2 kms, 16 stations, trains with maximum speed of 100 km/h, and an overall cost of $2.3 billion. The construction began in August 1996, inauguration was December 2004 and revenue service effective June 2005.

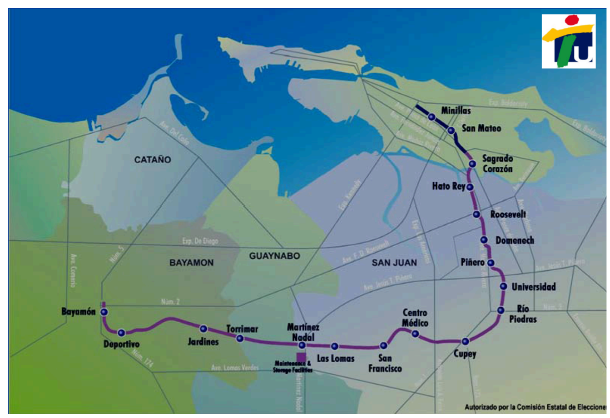

Fig. 1. Tren Urbano Alignment First Phase SJMA [1]

II. Key PDP Partners

The Tren Urbano Professional Development Program (TU-PDP) was the first PDP initiative that resulted from this Urban Mega Transit Project. This initiative established in 1994, was an interdisciplinary, bilingual, multi-cultural, multi-campus program sponsored by the Puerto Rico Department of Transportation and Public Works (DTPW), in conjunction with the University of Puerto Rico (UPR) and the Massachusetts Institute of Technology (MIT).

The primary objective of the TU-PDP is to develop local professional leaders in transit system planning, design, construction and operation. The secondary objectives are to strengthen the educational and research programs in key infrastructure-related disciplines at the University of Puerto Rico; to establish a model for cross-disciplinary cooperation among UPR faculty in engineering, architecture, and urban planning, working together with experts from government and industry; and to develop a collaborative relationship between the UPR and MIT [2].

The second PDP initiative refer herein as ATI-PDP, was established in 2004 and replaces MIT partnerships with the Polytechnic University of Puerto Rico (PUPR) and expands the Tren Urbano concept with the Integrated Transportation Alternative (ATI), which includes all public transportation components namely, Public, Urban Train, Metropolitan Bus Authority (MBA), Metrobus Bus System.

III. Program Components

Both PDPs consist of fundamental components which are focused on providing students a well-rounded academic and practical professional formation. The TU-PDP program consisted on six primary components shown in table 1.

Table I. PDP Program Components [2, 3, 4]

Component 1	**MIT Summer Short course on Public Transportation in Boston** *(June or July)* Introduction to Tren Urbano Project Introduction to Public Transportation History and development of Boston's transit system Field trips to MBTA, Central Artery Project, and others Best & Worst of Boston Team Project MIT student research presentations Recreational / Cultural Activities Cultural immersion in transit-oriented city *(for UPR students)*
Component 2	**UPR Short Course on Tren Urbano & Transportation in Puerto Rico** *(January)* Update on Tren Urbano Progress International Transit Systems Existing Public Transit in SJMA Student Research Project Poster Exhibit One-on-one meetings with Tren Urbano staff Field trips to view construction progress Helicopter Tour of Alignment Cultural immersion *(for MIT students)* Recreational / Cultural Activities
Component 3	**Student Research Project** *(during 1 or 2 years)* Research topic selected based on project need and student interest
Component 4	**Professional Practicum / Internship** *(Summer)* Internships with Tren Urbano consultants and contractors Placements made according to available positions & student interest Mid-term and final evaluations
Component 5	**Site Visit to Operating Transit System** *(Spring break)* Study and observe operating rail transit system Compare / contrast with Tren Urbano Dialogue and exchange of ideas with professionals of different disciplines
Component 6	**Employment opportunity with contractor or consultant** Experience gained during the summer internship and the leadership skills developed during PDP experience open a window of opportunities for potential employment

For the ATI-PDP, components 1 and 2 were consolidated with a short course on Public Transportation and related disciplines offered during the fall of each year.

Faculty mentors played a significant role in the professional development program. For example, the instruction at MIT presents both details and broader considerations of public transportation. It includes history, design, construction, operations and maintenance of public transportation facilities. MIT professors from Civil Engineering, the Department of Urban Studies and Planning, and the Center for Transportation Studies participated in the program. Professors were complemented by local professionals, transportation officials and community activists from the Boston area and around the country which strengthen the breadth of experience needed to have an interdisciplinary multi-campus experience [2, 4].

Case studies of specific transit lines are used to organize the presentation of course material, and to focus the field trips. For example, the Boston's Southwest Corridor Orange Line is presented to illustrate a design process with active community participation, and how the resulting line has achieved public support, personal security and even substantial volunteer maintenance of the parkland that was built as part of the transit project [2, 4].

Boston transportation projects are also placed in the context of land-use and development; local, state and federal policies and politics; economics, and environmental considerations [2, 4].

Non-academic contact at the dinners, evening events, and a weekend excursion to Vermont provide an opportunity to students and faculty mentors to interact and exchange experiences regarding culture and traditions. This interaction helps us better understand the different approaches that the students tackle a particular problem during the design, construction, operation and maintenance of heavy rail projects in an urban setting.

In summary, the summer course at MIT is intended to provide an intense introduction to the central issues of public transportation through expert presentations and the direct experiences of the students. It also serves to spark students' curiosity about particular topics that will become the focus of their research for the coming year [2, 4].

A. The Research Experience (Academic Semester)

In the fall, students at each participating university select research topics, under the guidance of their faculty advisor involved in the PDP. UPR engineering students were primarily undergraduates, while planning and architecture students are graduates. Undergraduate students conduct research for six credit hours per year as part of the undergraduate research course. They must submit a technical report of their research to fulfill a requirement of the program.

The research program has focused principally on transportation systems, construction management and urban planning, with a strengthening emphasis on the procurement process and construction management as the project has now moved into the construction phase. Transportation has been a strong area from the outset both in terms of aspects of the rail system itself and particularly the improvement of the existing bus and Público systems and their effective integration with Tren Urbano. An important emerging area is the analysis of alternative extension strategies and priorities.

B. Summer Internship

Undergraduate and graduate students have the opportunity to work during the summer in a ten-week, full-time internship with Tren Urbano contractors and consultants. The internship experience is coordinated by the Tren Urbano Office through its technology transfer department. The internship has the two main objectives namely, to provide students a meaningful and professionally-relevant work experience, and to provide a forum for professional development [2, 4].

Transportation planning, architecture, urban design, safety, quality control, technical services, field engineering, geotechnical, traffic engineering, vehicles, systems, scheduling and project management are examples of the areas for job opportunities associated directly with TU-PDP and subsequently with the ATI-PDP. Summer internships were offered in San Juan, Puerto Rico as well as in Boston, Massachusetts; Sacramento, California; and Minneapolis, Minnesota.

Students spend ten weeks at their work sites and participate in bi-weekly lunch-time meetings. Meetings were designed to enhance professional development and the other two are evaluation sessions. Evaluations are both written and oral. The summer internship culminates with a recognition evening for interns and supervisors. Internships frequently lead to jobs, particularly when the student graduates in June, does the internship in June & July and is hired in August. After the internship students also return to the university to complete academic work, while others go on to pursue graduate studies [2, 4].

C. Tour of Operating Transit System

During Spring Break, the UPR students and professors visit another city to study first-hand another rail based transit system. This is a formal two to three day activity including lectures, panels and visits to stations, the control center and maintenance facilities. The students have a strong background at this time so they absorb all the information provided them and contrast and compare the projected San Juan system and the Boston system. The systems visited since 1994 are Caracas, Venezuela; Miami, Florida; New York City, Medellín, Colombia; Bilbao, Spain; Houston and Dallas, Texas; and Washington, D.C. [2, 4].

D. Work Opportunity with Tren Urbano Consultant or Contractor

Once the students complete the summer internship and their studies toward their respective academic degrees, every effort is made by the PDP Director to place them in an entry-level professional job with one of the companies working on the Tren Urbano project. Placement with these companies varies upon the availability of positions and the volume of Tren Urbano work.

E. PDP Benefits

The two Professional Development Programs (TU-PDP, ATI-PDP) have contributed significantly to the workforce in engineering and education. Over 325 participants have benefited from both PDPs namely, 192 there have been 145 program participants (186 from UPR, 103 from MIT, 14 from PRHTA, and 22 from PUPR). Approximately 70% of the PDP participants have been hired by Tren Urbano contractors and consultants, as well as government agencies associated with public transportation, including leadership positions in their designated positions.

PDPs have been a win-win experience for university, government and private entities involved in this innovative programs; it increased student research exposure at a variety of academic forums namely, NSF Experimental Project to Stimulate Competitive Research (EPSCoR), its Junior Technical Meeting, COINAR Annual Congress sponsored by the College of Engineers and Surveyors of Puerto Rico, and Forum to Promote Engineering Research (FoPER).

The investment in the PDPs, results in valuable long-term benefits for the Commonwealth of Puerto Rico, namely, strengthened teaching and research programs in the College of Engineering, the School of Architecture, and the Graduate School of Planning, and significantly increased public transit professional expertise.

The academic advantages for MIT or other universities most likely McMaster University in the near future reside in the real-world experience, applied research, interdisciplinary perspective and cross-cultural interaction. Both PDPs provided an extraordinarily stimulating practical application of the theories presented in the University's coursework. The summer program in Boston, the winter program in San

Juan, and student research projects all give students intimate knowledge of the specifics and broader aspects of real transit projects.

PDPs also provides a parallel in the academic environment of the collaboration between disciplines that is required in the creation of successful transportation projects. This collaboration, emphasized in the winter and summer courses, is a feature of the presentations and discussions at the weekly student/faculty meetings during the year and in the organization and supervision of research projects.

F. *Ingredients for Success in Mega Projects*

The importance of using real projects as a centerpiece for the academic pursuits of teaching and research seems readily apparent to those intimately involved in the UPR-MIT Program. The students who have participated in the program, both from MIT and UPR, have already found immediate use of their experiences in employment and further academic studies. More importantly, they are primed with skills and knowledge for a lifetime of multi-disciplinary, collaborative work.

The program has been successful because there has been strong commitment to the program from the very top of the agencies responsible for Tren Urbano - DTPW and PRHTA. There is an appreciation that the participating universities can indeed provide value to the project itself. There is mutual trust, respect and openness among all parties. The Tren Urbano project has sufficient size and innovative content to justify a program with extensive university involvement.

The TU-PDP as well as ATI-PDP have demonstrated that the development of a rail transit system and an integrated public transportation system can be a significant opportunity and learning laboratory for developing the future professional leaders who will shoulder the responsibility for excellence and efficiency in urban public transportation well into the 21st century. Public and private funds invested in developing the professional leadership capability in rail transit are paying dividends in the Commonwealth of Puerto Rico. Both PDPs are a living proof that transportation agencies, universities and private companies can work successfully in the formation of professional leaders for mega transit projects.

IV. How Capstone Can Be Adapted To Incorporate New Phases Of Mega Projects

The Capstone comprehensive engineering design course, required by the Accreditation Board for Engineering and Technology (ABET) in undergraduate engineering programs, provides a unique opportunity to students to be exposed to a design experience of a real engineering project with an interdisciplinary setting [5]. The first phase of the Tren Urbano Heavy Rail Project in San Juan Metropolitan Area (SJMA), as well as the integration with other modes of transportation (ATI) were successful in training the next generation of engineers, architects, planners, and business entrepreneurs in an interdisciplinary project with real controversies associated with permits, environmental issues, alignment relocation, tradeoff in public perception of accepting public transportation, and related issues. Faculty mentors that participated in these PDPs from the School of Engineering, Architecture and Planning from both public (UPR) and private (PUPR) in Puerto Rico can expand this knowledge and incorporate it on future capstone engineering projects with an interdisciplinary setting as well as muti-campus experience with McMaster University in Ontario, Canada. Research topics can be fine tune in terms of scope based on the previous experience with Tren Urbano and ATI. The lessons learned in environmental issues, permits, how to deal with the public, laws and regulations, tradeoff between disciplines, protecting the environment and guaranteeing ADA requirements to satisfy all users needs are examples of the benefits from these PDP that can be readily implemented in a Urban Mega Transit Project in Canada and Puerto Rico. Finally, cultural exchange between Puerto Ricans and Canadians in the development of safe, sustainable and cost effective infrastructure is a win-win scenario in this millennium.

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Use of Peer-Assessment in Problem-Based Learning Projects in a Civil Engineering Programme

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***Abstract*— This paper describes the use of student peer-assessment in a Problem-Based Learning (PBL) Civil Engineering programme in Ireland.**

The theory, rationale and implementation of peer-assessment in the context of engineering education are briefly reviewed. Its use to assess process performance in the Civil Engineering programme at the University of Limerick (CIVIL @ UL) is described.

The results of peer-assessments from PBL "triggers" from Year Two of the programme are examined in detail and discussed. Correlational analyses are used to test student peer-assessment of performance within the PBL group process as predictors of overall performance in a module. Overall performance is represented by the marks from tutor-assessed submissions, individual interviews and presentations forming part of the output from the PBL trigger in question. Qualitative aspects of the data are also discussed.

The paper concludes with some proposals for further development; in particular, the introduction of a self-assessment element and the provision of feedback on peer-assessment submissions.

Keywords—Civil Engineering, Problem-based Learning, (PBL) Assessment, Peer-Assessment

I. Introduction

Graduates entering the engineering profession must be more than simply knowledgeable in their domains of study – they must be capable of continuously assimilating new knowledge to successfully tackle and solve complex unfamiliar problems. There is therefore general consensus among the stakeholders in engineering education that the development of autonomous life-long learners must be a core objective of any professional engineering programme [1], [2], [3].

The idea of education as habit formation is not new, even in engineering education. Sir Charles Inglis, former Head of Engineering at Cambridge University expressed this idea when he stated 'the soul and spirit of education is that habit of mind which remains when a student has completely forgotten everything he has ever been taught'[4].

These attitudes and habits are not formed by transmitting content, but by "embedding work with appropriate content within an effective process" [5]. CIVIL @ UL has adopted PBL as an effective process to develop students with these attitudes and habits. The programme aims to be process led rather than content driven, with Problem-Based Learning (PBL) at its core, and as such it is unique in Ireland. It is focussed on:

- personal responsibility for learning;
- a research orientation;
- reflective practice;
- group working and
- communication and presentation skills. [5]

Student peer-assessment of contribution to group-based projects and problem solving has been adopted as one means of achieving the desired emphasis on process. Students are required to assess the performance of their peers in designated key areas within the PBL process and justify their judgement with comments.

This paper focusses on peer-assessment as implemented in the CIVIL @ UL programme, examining in particular its use in two Year Two modules. The relationship between peer-assessed grades for contribution to the group-work process and the subsequent tutor grades from the output from this process is examined.

II. Why Peer-Assessment?

Peer assessment can serve several goals. It can be used as a tool for social control, for assessment, for learning, for learning-how-to-assess, and for active participation of students [6].

Within the group process, peer-assessment can act as an extra motivation for students to work harder and perform better, knowing that peers will be monitoring and evaluating their contribution.

Peer-assessment can be considered as part of the self-assessment process, serving to inform self-assessment [7]. Through assessment of their peers, students can obtain a better understanding of the positive and negative aspects of their own performance. It encourages reflection on their own approach to the activity or task being assessed, further developing the metacognitive skills of students. It is also associated with providing students with a better understanding of what is required to achieve a particular standard [8].

Peer-assessment can be used across a variety of assignment types including written assignments, oral presentations, calculation based work and group/team projects [9].

III. PEER-ASSESSMENT AT CIVIL @ UL

CIVIL @ UL modules delivered through PBL are centred on a problem or "trigger". Individual modules can have a number of "triggers", depending on module format and duration. Students work in groups of four to six members (depending on class size) to develop solutions. Formal PBL sessions with tutor supervision are held twice weekly with laboratory sessions, design workshops and lectures on key topics provided in parallel as required.

During the module, students are required to submit one or two confidential assessments of each peer within their group, depending on the project duration. These assessments typically occur at the mid-point and in the final week of the project. A rubric is not provided for peer-assessment. The criteria are developed and agreed by the whole class at the start of the semester. Students are required to provide an overall comment to justify the marks awarded to each peer. Typically criteria agreed for peer-assessment include:

- Contribution to group discussion during formal PBL session;
- Preparation;
- Contribution to group discussion during informal meetings between formal PBL sessions;
- Attendance/Punctuality*

*Marks are awarded in each category with the exception of attendance/punctuality, where negative marking is used for absence i.e. attendance does not earn positive marks.

The final peer assessment mark awarded to each student is based on the mean mark awarded under each heading by each of the other group members. This mark is used for formal assessment purposes and accounts for between 2.5 and 5% of the overall module grade depending on the year in question.

Students who fail to submit a peer-assessment of their fellow group members receive a zero total mark for peer-assessment, regardless of the marks they themselves were awarded by their peers. Non-submittal of peer-assessment marks was not penalized in the analyses in this paper.

IV. METHODOLOGY

The data used in these analyses were collected over a four-year period (2011-2014) from PBL triggers undertaken by Year Two civil engineering students in the following modules:

- Structural Steel & Timber Design (CE4024) and
- Hydrology & Water Engineering (CE4014).

Both peer-assessment and tutor-assessed marks were converted to a ten-point scale for analysis. Correlational analyses were then used to test student peer-assessment of performance within the PBL group process as predictors of overall performance in the project in question. Overall performance was represented by the marks from tutor-assessed individual submissions, interviews and presentations on the output from the PBL trigger in question.

Qualitative analysis examining specific instances of mismatched values between the assessment types was also carried out by reviewing the relevant supporting comments submitted.

V. RESULTS – QUANTITAVE ANALYSIS

The number of peer-assessments submitted during each PBL trigger under consideration is presented in Table I. In all, a total of 148 students submitted a total of 792 peer assessments.

Table I.: Class size (Total peer-assessments obtained in brackets)

Trigger	2011	2012	2013	2014	TOTAL
CE4024	31 (156)	16 (131)	19 (61)	10 (18)	76 (366)
CE4014	30 (150)	16 (146)	19 (140)	7 (40)	72 (476)
Combined	61 (256)	16 (277)	38 (201)	17 (58)	148 (792)

An annual breakdown of peer-assessment response rates is presented in Table II. The rates are generally consistent, although there is a noticeable decline in 2014 where the class size was smallest. The overall response rate for submission of peer-assessments over the four-year period across both modules is 90%.

Table II: Peer- assessments response rates by year

Trigger	2011	2012	2013	2014
CE4024	97%	82%	84%	63%
CE4014	97%	92%	97%	77%
Combined	97%	87%	93%	72%

Mean peer-assessment marks were consistent across PBL triggers from both modules. Mean tutor-assessed project marks based on a combination of submissions, interviews and presentations were consistent and lower by comparison in all cases. In both instances Standard Deviations were almost identical. In summary, the variation in student peer assessment of process is similar to that of tutor assessment of output, however peer-assessments are on average 1.64 great than the equivalent tutor grading.

Table III: Mean marks and standard deviations (SD) based on ten-point scale

Trigger	Peer-Assessment		Tutor Assessment	
	Mean	SD	Mean	SD
CE4024	7.52	1.41	5.67	1.33
CE4014	7.19	1.47	5.79	1.36
Combined	7.36	1.44	5.72	1.34

Pearson product moment correlation coefficients (r values) between assessment types were calculated separately for each module and for the overall sample and are shown in Table IV. The null-hypothesis method was used to assess the significance of the correlation values obtained [10].

The method compares the calculated r with a tabulated r values representing the null hypothesis (or "no significant correlation"). Tabulated values vary with sample size and degree of certainty that a correlation exists. An r greater than the relevant tabulated value indicates the presence of at least some degree of correlation for a given significance level, p. e.g. for a given degree of freedom the tabulated r value for p=0.01 means that r values greater than this indicates there is a 99% probability that the correlation is significant and does not occur by chance.

Table IV: Correlation Coefficients between Peer-Assessment of Process Scores and Tutor Assigned Overall Project Grades

Module	r-value	Sample Size (n)
CE4024	0.574	76
CE4014	0.500	72
Combined	0.528	148

The results in Table IV show positive correlations between peer-assessment of process marks and tutor-assessed marks based on project output in each of the triggers examined and for the sample sizes involved may be considered as statistically significant.

VI. Qualitative Analysis: Accompanying Comments

Comments submitted by students to justify the peer-assessment mark awarded to fellow group members can be revealing. The submission of these comments was mandatory.

Comments accompanying peer-assessments often demonstrate the group work characteristics most highly valued by the assessor e.g.

"Showed great leadership during this project, organised our team… involved the entire team in any decisions, very punctual, always completed agreed tasks, very focused in tutorials and an excellent communicator"

The descriptive statistics presented in Table III show student peer-assessment marks are typically higher that the final project grade obtained based on the output produced. Looking more closely at the data, the recorded peer-assessed mark was lower than the project output mark in only 3% of cases, with the differences in marks ranging between 1.56 and 3.21. The comments accompanying the peer-assessments in these cases were reviewed to identify possible reasons for such variations.

These comments typically referred to difficulties these individuals had in working within the group environment, expressed quite explicitly in one case:

"Student A can often ignore the fact that he is in a group and not doing an individual project"

This is also illustrated in the case of another otherwise strong student (Student B) who received relatively low marks from his peers. Here, a fellow group member noted:

"Student B knows so much… (but) sometimes is just so out of tune with what the group is doing."

Another group member echoed this, stating:

"(Student B is) an asset to any team when he wants to be… during this project so far he has been rather distant and more focused on completing solo tasks… frustrating…ends up doing his own thing"

A third commented on a perceived behavioral change when in the presence of a tutor:

"When the tutor comes over Student B starts talking really well and is full of information, but once the tutor is gone it's as if he is drained!"

All of the above contributed to the combined low total of peer-assessment marks received by Student B.

The frustration of fellow team members when a strong student fails to fully engage with the group process can be clearly seen in this comment:

"Student C is a great asset to any team - when he wants to be"

While in another case there seems to be an acknowledgement that the student in question is simply quiet by nature:

"(Student D is) very quiet. Doesn't speak or contribute until he is asked. Keeps information to himself. Mostly just sits there quietly"

In addition to clarifying the reasons for assigning a peer a particular mark, it is clear that supporting comments provide a valuable insight into the workings of the group. The confidential nature of the comments allow for frank and honest assessments. The provision of supporting comments for peer-assessments continues to be mandatory for all PBL triggers.

VII. Conclusions

There appears to be a correlation between how a student is perceived by their peers to be engaging in the group process during a project and the overall grade obtained for the project. This is in line with the findings of similar studies of peer- and tutor assessment [11].

Typically student peer-assessment grades were higher than the final project grade ultimately obtained. Students appeared to be unwilling to grade their peers at the lower extremes of the levels of performance. This is clear from the distribution of the individual peer-assessment marks submitted, where only 9% of the marks submitted were less than 3 out of 5 (Table V).

Table V: Distribution of peer-assessment marks

Mark Ex. 5	1	2	3	4	5
Distribution	2%	7%	26%	46%	20%

The final project grade exceeded peer-assessed grades in only 3% of cases. It was notable that in all cases the students involved scored a relatively high final project mark (mean mark = 8.21) by comparison with the overall mean final project mark of the study group (= 5.72). On examination of the accompanying comments, it appears the low peer-assessment marks were due to a perceived lack of engagement with the rest of the group as opposed to a lack of ability to contribute.

VIII. FUTURE ADJUSTEMENTS

At present feedback is not provided on submitted peer-assessments. Although studies have shown that provision of such feedback alone does not lead to directly improved correlations in the case of peer- or self-assessment [12], improved feedback as part of a more structured and guided approach to peer-assessment should be considered.

Asking student to provide a self-assessment by the same criteria as the current peer-assessments may encourage greater reflection on their own contributions to the group process. The standardisation of the peer-assessment criteria across the programme to allow students to develop greater familiarity with the system and the expected levels of engagement should also be considered.

Students require motivation to authentically engage in the peer- (and self-) assessment process rather than merely viewing it as a "box-ticking" exercise. Making clear the link between these forms of assessment and the development of the skills required to become the effective life-long learners so in demand in the engineering profession is key to providing this motivation.

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Collaborative Testing as a Way to Enhance Student Learning

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Abstract—**Learning is a social endeavour and collaboration is a technique used to enhance deep learning. In a tutorial or class environment, some students may not come prepared for the learning experience. Introducing collaboration into testing allows students to learn during evaluation when they are most likely to be prepared. Collaborative 2-stage midterm exams have recently been used in both the Faculty of Engineering and the School of Nursing at McMaster University with overwhelmingly positive student review. Pros and cons of self-selection versus random group makeup will be discussed, as well as some of the findings in the literature about this type of testing. One of the perceived drawbacks of this technique is mark inflation, we will present data showing that increases are minimal and the procedure is worth the effort based upon gains in learning and student satisfaction.**

Keywords—collaborative testing; group work

I. Introduction

Due to the social nature of learning, a great deal has been written about the benefits of collaboration as a way of enhancing learning. Much of this has been devoted to the introduction of collaboration into group projects or tutorial exercises [1]. Although there is evidence of the value of these techniques for learning, there is also the potential for students to come unprepared and for "social loafing". Over the past few decades, a number of studies have examined collaboration as part of the assessment process [2, 3, 4]. Preparation is usually optimal in a testing situation, and an additional benefit, shown by some groups, is a reduction in the anxiety associated with testing [5, 6]. Collaborative tests have been instituted in a number of different ways, from all marks coming from the collaboration, to different portions of the marks derived from a combination of individual efforts followed by collaboration. Differences have also been reported in whether or not the groups are required to come to consensus on the test answers.

A presentation regarding 2-stage exams by teaching fellows from the Carl Wieman Science Initiative at the University of British Columbia (UBC) prompted a joint pilot study of collaborative testing at McMaster University between professors in the School of Nursing and the Department of Chemical Engineering this year. This paper reports on collaborative testing results taken from these two different bodies of students. We use these two case studies to convey the concept of collaborative testing, citing literature elements that support, and those that suggest dissent. Before proceeding with those details, the logistical aspects of a 2-stage collaborative test are described.

II. Logistics

Students complete the written midterms individually first, followed by a short period of group formation, before commencing with the group portion. The group portion is a repeat of the original test, though it is conceivable to use other, similar questions. Groups may be self-selected or randomly assigned. The point in time at which group selection takes place is strongly dependent on class size, with a more formal process required to maintain order in a large venue. If the two stages are held back-to-back, then a 60:40 ratio of time is required for the time split, as was done in the nursing study. In the engineering study the collaborative portion was held during the tutorial slot a day or two later.

The collaborative portion is loud and busy, with students discussing their answers in groups of four. This group size is intentional, as students are clearly instructed to reach agreement on their answers. Groups of 3 or 5 are used to complete the class when it is not a multiple of 4. The group submits one solution booklet and grading sheet. In the nursing study the class was talkative, but otherwise the regular testing protocols were followed. In chemical engineering students were told than any resources, internet, instructors, teaching assistants (TAs) and textbooks could be used, for reasons described later.

Instructors and TA's then grade the individual and group portions, leading to an increased workload of about 25%. In the nursing study, students piloted the "Quest" software, developed in the chemical engineering department for the collaborative portion of the midterm examination. Students accessed the questions via computer, tablet or smartphone through a link they received by email. The program was set to time-out at the conclusion of the exam period, thereby limiting access to the questions after the test. The software automatically grades the test, collect metrics on time spent on each question, number of times the answer was changed, as well as question difficulty, and ability of the question to discriminate between those who did well on the test versus those who did poorly. The Quest program can be employed with both multiple-choice, fill-in-the-blanks, and even longer form questions. The caveat for use of the Quest software is a reliable network connection in the venue.

In both the nursing biochemistry and pathophysiology course collaborative tests, students self-selected their groups and participation was mandatory. In chemical engineering the first midterm used self-selected grouping and the second was randomly assigned. Participation in the collaborative portion was optional. Greater student participation was observed in the second midterm (90) over the first (75).

The above clearly highlights the flexibility required for this approach, this is the reason the technique was only feasible for midterms and not final exams, which are centrally scheduled by the university administration.

III. LEARNING BENEFITS

One question that comes to mind foremost is whether the extra instructor time to set up the collaboration is worthwhile. Since groups of 4 are enforced and there is a requirement to come to consensus (not majority), we hypothesize that those students who have a thorough grasp of the material gain valuable skills having to verbally explain their thought processes to their peers. This meta-cognitive action is thought to entrench their understanding and ability to apply the material.

Students who have an average understanding of the material can take satisfaction in the reinforcement of their learning and confirm their understanding is not off the mark in comparison with their peers. This collaborative process also helps them see other approaches to solving the problem, or identify shortcomings in their knowledge.

Finally, students that currently have a poor understanding of the concepts are given an opportunity to see how their peers tackle the problem. This is a far less intimidating process than requesting assistance from a TA or instructor. Peers have been shown to possess a remarkable ability to explain concepts to their colleagues [6], being novice learners as well who do not yet suffer from "expert blind spot" [7] and so can better identify the step(s) with which they struggle.

The UBC model, which was recently published [8], highlights the value of the process for all students, not just the lower performing students. Their paper also provides evidence for retention of gains made during collaboration; they try and solve the controversy in the literature, where some researchers found retention [3] and others found no effect [9] due to collaborative testing.

The gain in grades, described in the separate section below, does obviously not equate directly to gains in learning, nor does it guarantee whether gains in learning, if existent, are in fact retained. This is the focus of ongoing work. However, what was consistently witnessed by the instructors was a positive atmosphere, heightened noise levels, and the distinct visual picture of students achieving a deeper understanding of the concept at that moment. This is because of the way the collaborative test was administered.

The fields of engineering and nursing place emphasis on collaborative skills. The requirement for the teams to reach consensus in the approach described in [8] provides practice for these skills along with creating an environment conducive to deeper learning.

The group exam also provided the advantage of allowing students to get a read on how well they had performed on the individual test. Students immediately informed the instructor that there was no need to review the midterm in class, since the collaborative portion was their review. Such a review is certainly far more complete than any in-class review could ever be.

Based on all the above benefits, many unquantifiable, we plan to continue to incorporate collaborative two-stage exams into our courses, refine the process, and engage in research to better assess its benefits.

IV. STUDENT SATISFACTION AND PERCEPTIONS

Features of collaborative testing that do not seem controversial are enhanced student satisfaction and test performance [10, 11, 12]. While our experience with collaborative testing was positive, students continued to provide comments confirming their satisfaction on the end of semester course evaluations. In addition to satisfaction and perception of enhanced learning, students also provided feedback on helpful behaviour that this type of assessment engenders.

Students reported feeling obliged to study harder so as not to let their groups down or look incompetent in a group in which they were randomly placed. Most reported experiencing less stress knowing there would be an opportunity to discuss test questions after their individual efforts.

Some of the comments received surveying the Fall 2013 N2LA2 Pathophysiology students in the School of Nursing were:

"*Discussing concepts with other students allows students to get a better understanding of course concepts and also gives insight into their own understanding of course concepts*"

"*I liked the collaborative midterm because it allowed you to discuss possibilities, and gave you a chance to listen to other's ideas*"

In addition, the students in both engineering and nursing courses, who were surveyed about the midterm, unanimously enjoyed the collaborative style of testing. Course evaluations from chemical engineering were all positive, with one single negative review, in a class of 120 students (55 evaluations were completed). The engineering students were separately surveyed on their preference for self-selecting groups over random group assignments. Selected comments were:

"*groups assigned/randomly chosen were more realistic and encouraged the incorporation of different viewpoints*"

"*second midterm* [randomly assigned] *was less effective ... less willing to put forward ideas ... 1st midterm* [self-selected] *everyone was very vocal about their opinion and there was more effective teaching between all group members*"

"*helped to work with students other than your friends because you did not have experience with group members'* *preferences and learning styles. The random groups allowed for more collaboration rather than relying on the friend that you know understands the material to carry the rest of the group*"

The sentiment was a 50:50 mix of positive versus neutral-to-negative viewpoints. This is a topic we will continue investigating.

V. GRADING AND GRADE BOOSTS

Although student satisfaction seemed a universal element of collaborative testing, some of the literature referred to the drawback of grade inflation as a negative component. Molsbee [13] advised that collaboration be introduced without addition of marks due to the failures and withdrawal from subsequent courses of students who had their grades increased due to collaborative points. However, Sandahl [14] in her review of collaborative testing in nursing noted that studies she examined showed no students passed courses in which they would not have passed without the collaborative testing.

We present results on grading and grade boosts separately, since this an issue that many instructors seem to take issue with when initially evaluating collaborative testing. In our experience - and consistent with literature results - there was not a large increase in marks, certainly no student passed the course who would have otherwise failed. The learning observed and reported appeared to justify the very minor increase.

The UBC model [8], consists of 85% of the marks derived from the individual portion of the exam, with 15% contributed by the subsequent group effort. They report very modest boosts to the grades. This ratio was used in our studies. In the nursing first year biochemistry course an average gain of 2.8% on the midterm (including 416 students from the 3 different sites of the collaborative BScN program - McMaster University, Mohawk College and Conestoga College) was realized. Since the midterm comprised 30% of the final mark, only a 0.8% increase in the final course grade was attributable to collaboration during the midterm.

The second year pathophysiology course is a full year course and was run with 2 collaborative midterms. The increase in marks over individual efforts on the first midterm was 1.6%, with a 2.4% increase on the second midterm. With each midterm contributing 20% to the final grade, again only a 0.8% total increase in marks was seen due to the collaborative portions of both midterm exams.

Similar boosts in chemical engineering were observed; the median upward shift reported was less than half a point on the 12-point grade scale. This boost was split across two midterms. In the first the ratio was 80:20 which led to a median increase of 3.6%, while the 85:15 ratio led to a median boost of 1.5%. These results are shown in Figure 1.

The figure for the first midterm shows a large boost in a small number of student cases: these are students that self-selected their group in a very advantageous manner.

Note that while a negative boost was calculated, it was not applied (this would be a student that performed well individually, but was not able to convince her/his group members that his/her answer was correct). This is because both nursing and engineering students were clearly informed that students who outperform their group keep their individual mark at the 100% weighting. Students tend to be more receptive to trying this form of testing if they see it as a win-win situation, and there is no risk to collaboration.

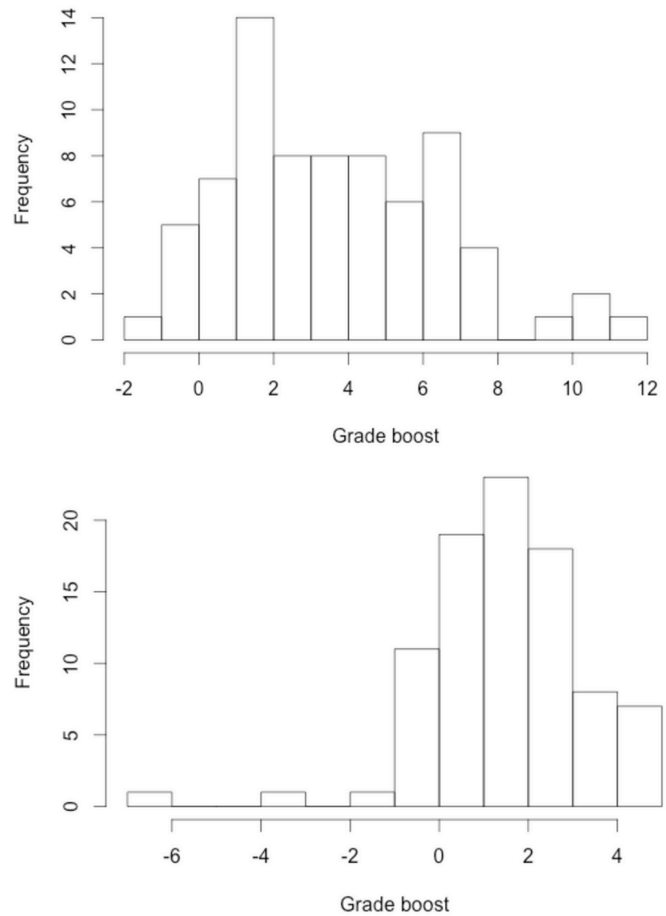

Fig. 1. *Top*: grade boost from the first midterm [self-selected groups; *bottom*: grade boost from the second midterm [groups randomly assigned].

The prior literature reports regarding very small grade boosts was the main reason why the engineering midterms were structured as "anything is allowed" during the collaborative portion. The message was clearly conveyed to the class that the focus was on learning, and not on testing. This shift in attitude is instrumental in creating an effective, relaxed learning environment.

Students requiring academic accommodations cannot always participate effectively. If their individual tests, and logistics allow for it, they can participate in the collaborative portion later in the day. However, they can choose to take the average of all of the groups if they did not wish to participate, or if their schedules did not allow for the extra time required before the collaborative portion of the test.

VI. Conclusions

As mentioned, many of the gains are not directly quantifiable. Future work on this project includes creating a study to test for learning gains and retention. We will continue to incorporate collaborative 2-stage exams into our courses, experimenting with various parameters, and engage in research to better assess its benefits. Work is underway to add additional code to the Quest software to allow for immediate feedback, or where internet connectivity is insufficient the use of Immediate Feedback Assessment Technique (IFAT) [15] scratch cards will provide greater benefit to students to further enhance their learning.

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An approach to teach software architecture quality driven by non-functional requirements

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***Abstract* — Software architecture quality directly affects the user's perception of system overall quality, since it defines if the quality systems requirements will be achieved, especially the non-functional requirements. Nevertheless, architecture quality concepts are not handled with due importance by the curricula of undergraduate and graduate software engineering courses. This paper proposes a guide for teaching software architecture quality based on non-functional requirements and presents the results of the application of this guide in undergraduate courses.**

Keywords—Software architecture, software quality, non-functional requirements, education;

I. INTRODUCTION

Quality is increasingly seen as critical to business success, customer satisfaction, and acceptance. Its absence may result in financial loss, dissatisfied users, and damage to the environment, and may even result in deaths.

Computer literacy is rich of many of software failures examples related to poor software quality. Some instances: Therac-25, a computer-driven radiation system, seriously injured and killed 7 patients by massive overdosing [1]; the lack of an exception handling in a conditional statement lead to a F-18 plane crash; a reversion in Oregon Elections caused by software errors [2]; more than 100.000 people affected in 234 billion by the U.S. Social Security System that could not handle non- Anglo-Saxon names [3]. These examples are related to software quality, principally to non-functional requirements.

Quality attributes of large software systems are principally determined by the system’s software architecture. That is, in large systems, the achievement of qualities such as performance, availability, and modifiability depends more on the overall software architecture than on code-level practices such as language choice, detailed design, algorithms, data structures, testing, and so forth. This is not to say that the choice of algorithms or data structures is unimportant, but rather that such choices are less crucial to a system’s success than its overall software structure, its architecture [4].

The non-functional requirements of software architecture play a key role in terms of the specifying the design patterns and deployment architectures of the solution being built. For example, poor network connectivity will dictate requirements in terms of a centralized vs. decentralized deployment, requirements for resilience may dictate a requirement for clustered hardware, etc. To implement these architectural decisions and thus to design the whole architecture it is essential that the architect knows its most relevant quality attributes [5].

Although software architecture and its influence on non-functional requirements are widely regarded as one of the most important software artifacts, in many cases real-world application of software engineering concepts does not effectively map with current software engineering curriculums. Typically, a student’s first real-world experience working on large-scale software development projects and software quality attributes is in his/her first full-time position [6].

An ordinary student is used to writing small programs, from scratch in a language, without architectural quality guidance. Students have strong programming skills, but very seldom know architectural concepts and their influences on software quality. These students tend to immediately start coding once they receive a problem to be solved [7].

This result in a serious gap in software engineering curriculum: students are expected to learn how to design complex systems with lots of non-functional requirement without the requisite intellectual tool for doing so effectively [8].

This paper presents an approach to teach software architecture driven by non-functional requirements in order to anticipate the learning of impacts of non-functional requirements in software architecture supported by Architecture Tradeoff Analysis Method (ATAM) [9], ISO/IEC 10746 (Reference Model of Open Distributed Processing - RM-ODP) [10] and ISO/IEC 25010 - Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - System and software quality models [11]. The proposed approach has been applied in advanced software laboratory undergraduate discipline in Computer Engineering courses since 2007.

II. AN APPROACH TO TEACH SOFTWARE ARCHITECTURE QUALITY DRIVEN BY NON-FUNCTIONAL REQUIREMENTS

The proposed approach has considered the following competencies for teaching software architecture quality guided by non-functional requirements described in the Software Design Document Computer Science Curricula 2013 [12].

- Understand the impacts on the quality of the software product resulting from architectural decisions;
- Define the architecture of software to be used according to the quality requirements demanded by business needs ;

- Understand the implicit non-functional requirements in business process;
- Evaluate different alternatives of software architecture for the implementation of a system considering the trade-offs between non-functional requirements of an application;
- Use assessment techniques to guide architecture architectural decisions;

To develop the skills described, understanding the relationships between software architecture and critical business processes, trade-offs between quality attributes and measurement of software quality is very important. The concepts of ISO / IEC 10746, ISO / IEC 25010 standards and ATAM supported the teaching approach presented in this article. The proposed approach has the following technical and pedagogical characteristics:

- Practical approach: usually software architecture quality and its metrics are presented in a very theoretical and abstract way, but the students have weak intuitions about high-level architectural abstractions and quality attributes. Real world examples of software architectures metrics, collected from practical examples, lead to a better understanding of its concepts and quality tradeoffs.
- Problem-based learning: engineering education is undergoing significant changes, notably in the way engineering schools are adopting problem-based instruction to meet the changing demands of engineering practice. Mastery of technical content is no longer sufficient. Increasingly, engineering programs are requiring students to work projects that are open-ended with loosely specified requirements, produce professional quality reports and presentations, consider ethics and the impact of their field on society, and develop lifelong learning practices. An implicit goal of this shift in curricula is to produce graduates who will be ready to assume engineering tasks upon graduation—that is, with the skills to develop solutions to problems under competing constraints of functionality, cost, reliability, maintainability, and safety. In problem-based learning, students are actively involved with problems coming from real practice.
- Quality requirements metrics: quality requirements impact directly on measures such as productivity and cost. Ultimately, these quantitative measures determine the justification for investment in a software development project. In view of this reality it is surprising that non-functional requirements are often ignored in the analysis process [13].
- Simulation techniques: Simulation has been used in engineering disciplines for many years to great advantage. In recent years, an increasing amount of attention has been paid to using simulation to advance software engineering. There are a number of areas in which simulation can benefit software engineering, including: assessing the costs of software development, supporting metric collection, building consensus and communication, requirements management, project management, training, process improvement, risk management, and acquisition management [14]. Simulations can also produce visualizations of the architecture's execution. These visualizations are particularly useful for identifying software architecture failures as bottlenecks points, resources starvation, memory leaks, low performance, etc. Simulation, done during the architecture and design stage, is also a low cost alternative to the actual implementation and execution of a real system.
- Intensive use of proof of concepts: proof of concept is used as evidence that the chosen software architecture is viable and capable of meeting quality attributes requirements and related business drivers.
- Real-world projects: incorporating real-world problems of sufficient magnitude and complexity into the classes is necessary to enable effective learning of software architecture quality skills and concepts.
- Incremental learning: knowledge is often hierarchical, and frequently the best way to assure performance on higher-level objectives is to identify the prerequisite skills needed for a current unit of instruction and ascertain that students have mastered them.
- Learner-based teaching: traditional education practice seems to be built on an assumption that the mind is a container, and it is the teachers' responsibility to fill this with knowledge. Learner-based teaching means that education is not viewed as a process where knowledge is transferred from the teacher to the student, but rather that knowledge is create within the students' minds. The teaching approach adopt a practice driven education model where software architecture quality concept is regarded as something which cannot be taught entirely, but must be built by each individual requiring a engaged and proactive attitude on the part of students. This approach, which goes from the concrete to the abstract, capitalize on the innate human desire to explore and learn that is characterized by "practice-pull", rather than "theory-push" [15].

In order to create a learning scenario, the project should not start from scratch but should start with an existing system that needs to be measure, extended, modified and measured again.

After challenging the students with of a real world project assignment, the primary strategy was to involve and motivate them in a full life cycle team project, where the teacher plays the role of "the client". This gives the students first hand personal experience in the effects of making architectural decisions on their project and on the clients' satisfaction with their product. The Java Pet Store 2.0 has been used as system sample.

The Java Pet Store 2.0 Reference Application is a sample application designed to illustrate how the Java Enterprise Edition 5 Platform can be used to develop an AJAX-enabled Web 2.0 application, using Java Persistence APIs, applying MVC and other design patterns in an Ajax web app, using Mashups such as Google Maps service for location specific searches of pets and PayPal service for purchases, using an RSS feed as a data source [16]

The steps in the next picture are followed to teach software architecture driven by non-functional requirements:

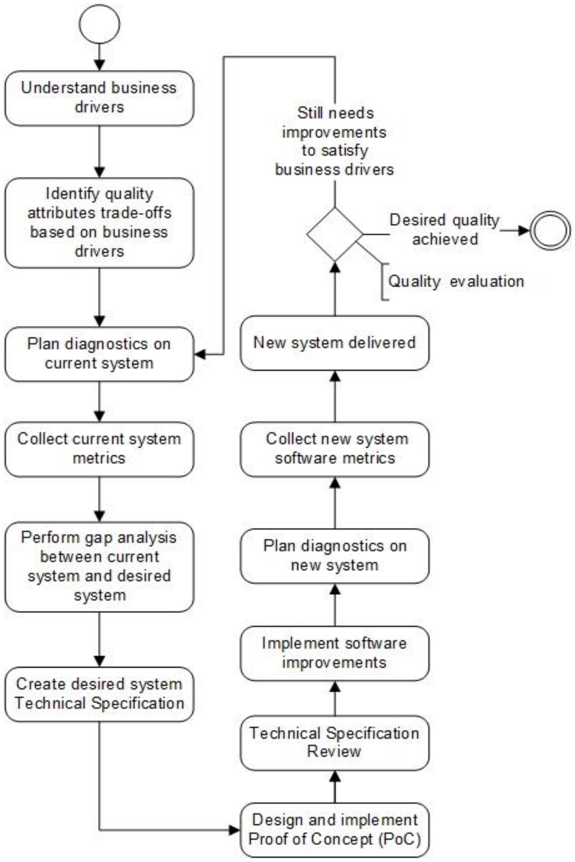

Fig. 1. Steps to teach software architecture quality driven by non-functional requirements.

Here is a description of each step:

- Understand business drivers: in this step, the students understand the concept of business drivers and how it drives software architecture.
- Identify non-functional requirements tradeoffs based on business drivers: here ATAM concepts are discussed and the course work assignments are distributed to teams of 2 or 3 students. It involves software improvement considering, but not limited to, the following tradeoffs:
    - Maintainability vs. usability;
    - Security vs. performance;
    - Concurrency vs. simultaneous access;
    - Accuracy vs. concurrency;
    - Availability vs. portability;
- Plan diagnostics on current system: using tools as JMeter [17], an application designed to load test functional behavior and measure performance, the students plan diagnostics of measures on current system related to the course work assignment, i.e., the tradeoffs. The measures include static and dynamic metrics.
- Collect current system metrics: collect the metrics on the current system according to the plan defined in the previous step.
- Perform gap analysis between current system and desired system: with metrics results, each team performs a gap analysis between current system and the non-functional requirement attribute desired in the new system's implementation. For instance, in the security vs. performance team, the challenging is to improve system security considering the overall system performance.
- Create desired system Technical Specification: in this step, a technical specification of the desired system is created. The specification is a lightweight document, containing only enough information to implement system desired improvements;
- Design and implement Proof of Concept (PoC): the implementation of a Proof of Concept is very important in the learning process. The goal is not just confirm that an implementation is feasible, but also demonstrate its weak points. To do so, the students apply many useful technics as simulations, loopbacks, injections, etc. Here, the students learn how to choose architectural tactics. An architectural tactic is a reusable architectural building block that provides a generic solution to address issues related to quality attributes. Architectural tactics are selected based on a given set of quality attributes, and the selected tactics are composed to produce a tactic that combines the solutions of the selected tactics. The composed tactic is then instantiated to create an initial architecture of the application where the quality attributes are embodied [18]. After the choice of one or more tactics, they are implemented through a mechanism.
- Technical Specification Review: a formal review of Technical Specification conducted by student team supported by teachers in order to verify if the main aspects of architecture were considered. It can be considered the first test in the course.
- Implement software improvements: implementation of software improvements confirmed in PoC and detailed in technical specification.
- Plan diagnostics on new system: to verify if the software improvements were achieved a new cycle of measured must be done. At this time, in the new system.
- Collect new system software metrics: collect the metrics on the new system according to the plan defined in the previous step.
- New system delivered: new system released.
- Quality evaluation: presentation of new software architecture as well as the results of the new system metrics. This presentation can be considered the final test in the course. If the results were under the expectation, the process can be repeated, i.e., the system still needs

improvements to satisfy business drivers. Due course time constraints, the steps were executed only once.

In the classes, the students were able to analyze in practical way the quality requirements by an architectural point of view and its importance to meeting software quality. Under this learning scenario, others essential software engineering skills were also trained as team work, software project management, software architecture design and communication skills, in a realistic environment and in architectural-centric approach.

From 2007 to 2012, this approach was applied to 85 computer engineering undergraduate students. The evaluation of teaching approach has been done by a 3 phase-survey answered by the students. The first one is applied in the beginning of course. The second one, in the middle of course (7th. class – during Technical Specification Review), and the last one in the end of course (12th. class – Quality evaluation). In each survey, the student should answer his/her knowledge level (No knowledge; little knowledge; Average knowledge and Good knowledge) in software architecture quality and non-functional related topics.

Analyzing the students' answers, there are evidences that the concepts taught by the discipline were learned. The following picture shows the consolidated results of the 3 surveys applied:

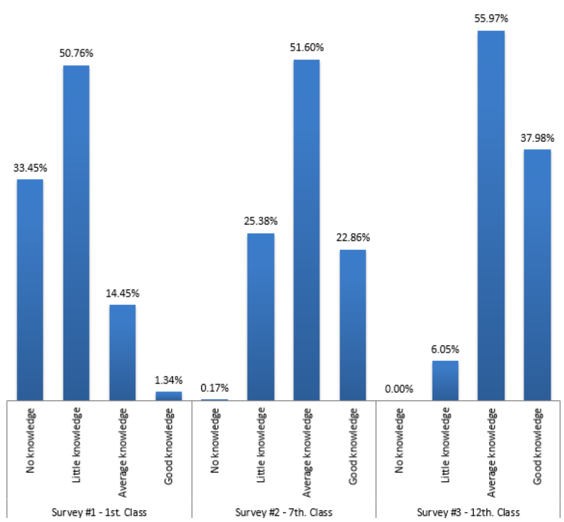

Fig. 2. Survey results

III. CONCLUSION

Teaching approaches related to software architecture and software quality has been developed by the authors since 2003 and has already been applied in more than 25 class groups, resulting in around 6000 class hours, including undergraduate and graduated disciplines and mentoring on the job activities. The students' feedback on the teaching approach has been very positive.

The authors believe strongly that including practical software metrics formally in software engineering curricula in order to obtain software quality from an architectural point of view can help the universities to achieve their core goals in higher education, supplying the growing demand of society for high skilled system architects.

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Teaching an introductory course in soil mechanics using problem based learning

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Abstract— Engineering a natural material to produce a structure with form and function can prove challenging for an undergraduate student. First encounters with soil as an engineering material can undermine a student's confidence in their analytical thinking. Moreover, predicting the behaviour and strength of soil with the same degree of certainty as other common engineering materials i.e. those which obey the well established theories of elasticity and plasticity is at the core of this unease. Unfortunately the mechanics of soil behaviour requires a broadening of the conceptual 'model' for interpreting or predicting its response when loaded. The struggle to move from continuum mechanics in the case of steel for example, to a particulate material in the case of soil disturbs the students fragile understanding already gained from such compliant materials. The challenge is often exacerbated by the lack of a unifying context within which the knowledge can be applied and tested.

In this paper we reflect on numerous iterations conducted over a seven year period delivering an introductory course in soil mechanics. The course is taken by the civil engineering (CE) and construction management and engineering (CME) programmes at the University of Limerick. The paper explains how the initial offering has changed to produce a carefully considered problem or trigger for learning so the intended engineering tenets are mastered. This is accomplished using a collaborative pedagogy which places small student teams at the heart of the learning process.

Analysis of student results over a five year period and feedback from the 2014 cohort gathered anonymously using audience response units (clickers) are presented. These are discussed in light of instructional changes made by the lecturer that have resulted in a significant upward trend in overall performance over the past two years. In the most recent instructional intervention, use of flipped learning resources and re-sequencing of core material delivery to be more in line with the demands of the Problem Based Learning (PBL) trigger appear to have contributed positively to this year's improvement.

Keywords—PBL, soil mechanics, student engagement, critical thinking, flipped learning;

I. INTRODUCTION

The role of education is to enable the learner to think about an unfamiliar problem, task or question and to exercise the power of judgment when seeking solutions to such challenges. Ilyenkov [1] promotes fostering a caring environment in which the students are encouraged to draw from prior knowledge and their life's experiences when formulating their research questions. He argues that genuine understanding can only be achieved if the learner personally travels the route mandated by the problem until 'insight' is reached and that this is best done through a process of dialectic reasoning. Ilyenkov is critical of the emphasis in secondary education of 'cramming' existing dogma or established 'truths' that themselves have been reached by the rigorous questioning of others but presented as 'absolute truths' without the necessary background as to how these truths were reached. He suggests this route cripples the students natural curiosity and renders them unable to find their own way to objective truths. The authors concur.

With this in mind, the University of Limerick developed a new bachelor's programme in civil engineering in 2008 [2]. A decision was taken by the programme designers to adopt a student centred pedagogy. This decision is based on the professional experience & intuition of the designers and is backed up by research on the requirements of engineering education in the 21st Century [3][4][5].

The UL programme adopts a strategy that focuses on the process of learning rather than just delivery of content. The pace of technological change and the rate at which new knowledge becomes obsolete has influenced this decision. From day one of first year, students on the programme are introduced to engineering through a series of open ended problems. Initially the problems draw from the students' prior knowledge encountered during second level education with the focus placed on small team collaborative learning through a Problem Based Learning (PBL) pedagogy. The knowledge sharing and questioning that takes place is carefully monitored and facilitated by experienced academics and industry practitioners. Then as the students progress through the programme the problems grow in complexity.

In this account, we present some interesting findings from a second year introductory course/module on geology and soil mechanics. Over the past seven years the content of the course has remained unchanged but the approach taken to facilitate learning has undergone significant adjustment. The influence of these changes and their impact on student understanding and attitudes to the subject matter are discussed in this paper.

Dealing firstly with the content; the course 1) introduces basic information on how to investigate a site to obtain appropriate geotechnical design information, 2) defines and calculates basic soil properties such as density, moisture content and permeability 3) applies the fundamental mechanics of particulate material behaviour based on the principle of effective stress 4) undertakes seepage analyses for earthen structures and 5) prepares written specifications for the construction and quality assurance of the construction work.

II. Course Structure and Assessment

The six ECTS credit course is run over a fifteen week semester. Twelve teaching weeks are followed by a study week and written examinations are run over the final two weeks. Each teaching week comprises five contact hours; two facilitated PBL hours, two individual lecture hours and one tutorial hour.

The course is structured around a single problem or trigger which is presented to students on the first day. In recent years the problem requires the students to design an earthen dam to bolster existing flood defences for a student village located on the flood plane of the River Shannon (Fig. 1). Scenarios such as this provides real context for learning as each student can contemplate having to solve similar problems in professional life.

Fig. 1. Student Accommodation during the floods of 2009.

Once the problem has been presented, students brainstorm to identify tasks they have to complete and the technical concepts they have to master to solve the problem. Output from each team is then compiled on a single whiteboard. Although students have a limited exposure to soil mechanics prior to this, by drawing on their prior knowledge and life's experiences the final output list is always very close to the course content listed in I above.

A work plan is then developed for the semester in collaboration with the tutors. Teams meet once a week for a two hour facilitated PBL session which generally involves a go-around to address research questions from the previous meeting, brainstorming to determine next steps and the creation of a new research plan. The teams also meet at other times during the week to keep their work on schedule. It is noteworthy that there are no predetermined sequence of laboratory experiments; the responsibility for identifying and execution of necessary tests lies with the dam designers.

Allied to this, technical content is presented in a 'just in time' schedule to provide appropriate scaffolding to support the synthesis of new material. The timing and method of delivery has evolved over the last five years as the new CE programme merged into the course already being taken by the existing CME programme. The merger in 2010 corresponds with the course moving away from a more didactic delivery to a student centred learning experience. The course is assessed using the criteria and weightings shown in Table 1.

Table 1. Course Assessment

Trigger Assessment				
Group video documentary + individual interview	Individual Poster + reflection	Technical paper review	Three online quizzes (best two counted)	Written Exam
35%	10%	5%	10%	40%

The video documentary and interview is given almost the same weighting as the end of semester written exam. As with the written exam, the interview permits each student's contribution and understanding to be assessed by the facilitators.

III. Course Delivery Improvements & Corresponding Trends

Fig. 2 shows the student performance trend over the past five years. Performance is measured in terms of improvement in the course Quality Point Value (QPV) normalised by the maximum mean secondary school points for the programme over the past five years. The QPV has a value between zero and four and students are required to achieve a minimum QPV of 2.0 to pass the course. The data shows a significant improvement in QPV in the past two years.

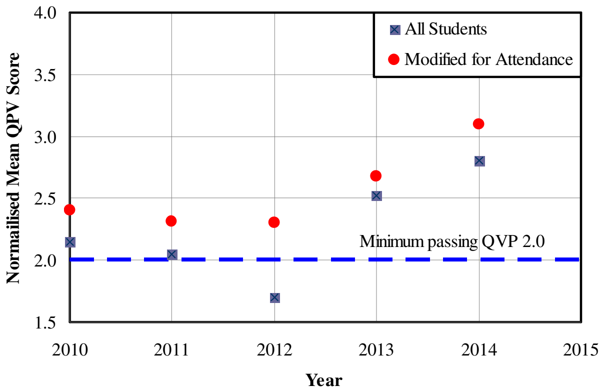

Fig. 2. Performance over the past five years in geology & soil mechanics.

As each cohort over the past five years are statistically similar with respect to their secondary school final examination points, the improvement is specifically attributed to teaching initiatives undertaken in these years. Fig. 2 also indicates the influence of students attending less than 50% of facilitated

PBL sessions on QPV. The teaching initiatives responsible for this trend are now discussed.

A. *Syncronising the Content to Meet Trigger Learning Needs*

Student feedback from initial iterations of the course indicated that the PBL format worked well and that the dam trigger provided an engaging context for learning.

It was suggested however that the most challenging content was being discussed too late in the semester. Topics such as effective stress and seepage were identified as important and relevant concepts in the facilitated PBL sessions. Teams undertook their own research in these areas but found they were ill-equipped to fully apply the concepts in the 'real world' dam design setting.

This was a source of frustration as the students struggled to work through their design without having received expert guidance on the fundamental principles behind these challenging concepts. This was addressed for the 2013 cohort by introducing the concepts much earlier in the semester. Minor tweaks in the schedule were again undertaken in 2014. Interestingly Fig. 3 shows that even with the earlier coverage of these topics the students feel the need for yet more time interacting with these concepts.

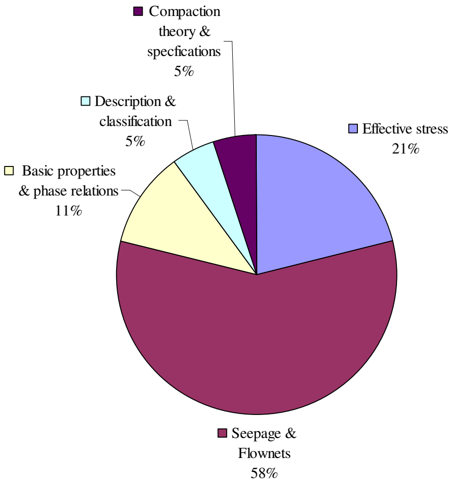

Fig. 3. Topics students feel requires additional time.

B. *Flipped Learning Initiatve*

The development of twelve short online videos (Fig. 4) providing specific subject context and knowledge was an initiative introduced in 2014. (The full video series developed as part of this initiative can be accessed at: http://www.youtube.com/watch?v=z4p6rp1knVY.) These videos enable the content to be delivered flexibly and facilitate a more productive use of contact time.

While the concept of the trigger has been in place since 2010, the interplay between the PBL sessions and the supporting lectures improved significantly with the introduction of the online videos.

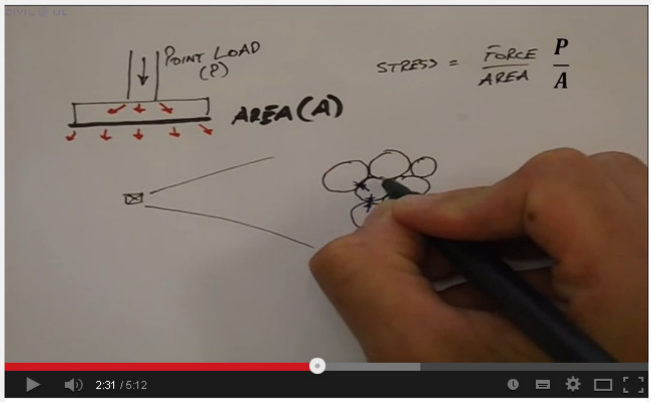

Fig. 4. Flipped learning video on effective stress.

This addition has been incorporated in the following learning cycle summary for the micro aspects of the trigger:

- A specific technical concept is identified in the PBL session
- Team discussion takes place and research questions are agreed. This is followed by a period of individual research
- The online videos may be consulted as part of this research
- The face to face lecture then allows for detailed discussion and clarification of any outstanding issues. Worked example problems are also undertaken in the lecture, and this leads back to
- Further team discussion and application of new knowledge in solving the trigger

Approximately 50% of the course is available for delivery using this 'flipped classroom' model. A post course survey on the initiative polled the 70% of the class (of 27) in attendance on the day of the survey. The responses shown in Fig. 5 demonstrate the videos have proven popular. This success has resulted in a plan to extend theses resources to cover the entire course content in the next academic year. Fig. 6 indicates there remains work to be done to obtain full student buy-in on the 'Flipping' philosophy of studying the content prior to attending the lecture.

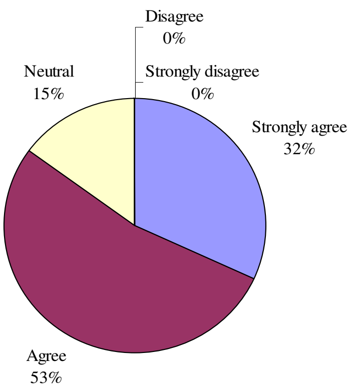

Fig. 5. "The YouTube videos helped me understand the topic covered."

However, because the entire course content is not available online at this time, viewing was recommended rather than mandatory in advance of lectures. Further iterations with a full suite of online course content will make pre-lecture viewing a requirement and participation will be encouraged through embedded questions to solve or ponder in advance of an in-class pop quiz. Moreover, some scaffolding or support is required to encourage the students away from their traditional didactic experiences and towards the flipped approach. This requires a feedback mechanism that clearly demonstrates mastery can be reached more efficiently by utilising available class time to work through the concepts and where the lecturer's experience and approach to solving problems can be modelled.

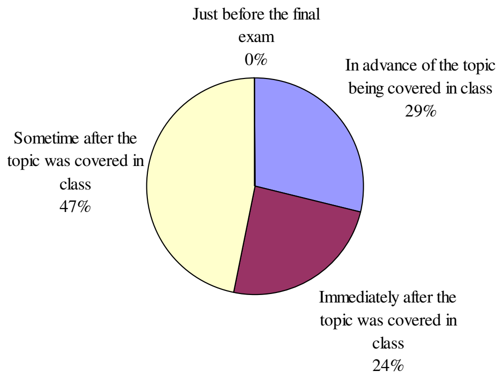

Fig. 6. When students viewed the online video resources.

C. Student Perception

Fig. 7 shows that the 2014 student cohort are broadly positive on the timing, relevance and delivery of the course content and the role it plays in facilitating the completion of their engineering challenge within the allocated time.

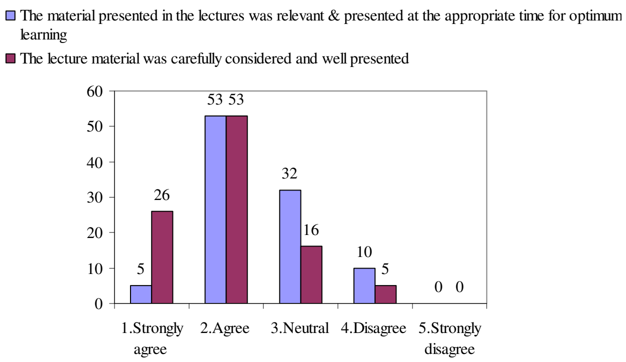

Fig. 7. Student opinion on the timing, relevance and delivery of course content.

Nevertheless, Fig. 8 shows that the 2014 cohort find the subject matter challenging but generally have a neutral or better opinion on their ability to apply the concepts in practice. Previous cohorts were also polled anonymously through UL's Centre for Teaching & Learning. These findings also suggest views presented in Fig. 6 are consistent with the opinions of previous cohorts. Unfortunately, as the feedback is gathered anonymously, it is not possible to determine if this is a generally held view of the class or is skewed by the larger number of CME students within the 2014 cohort. Eighteen out of twenty seven students are from the CME programme. Year on year the data shows the CME students are less likely to engage fully with this subject and generally have a poorer attendance compared to civil engineering cohorts. This perhaps reflects the perceived roles and responsibilities of each profession in the construction process; civil engineers realising expertise in soil mechanics is a mandatory skill for professional competence. CME students understandably see it as a discipline they interact with but not one they require to become successful construction managers.

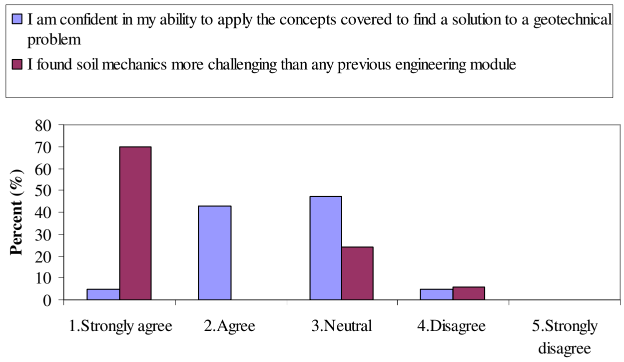

Fig. 8. Student subject perceptions.

IV. Concluding Comments

A PBL trigger is a useful mechanism for engaging the students within a given context and getting them to generate the necessary research questions to be answered. However, this paper has shown the necessary and positive influence that well timed supporting lectures allied with course specific online resources has on the technical competence of students. This is particularly helpful when dealing with such a complex material as soil.

Acknowledgment

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Technology and Intervention-Based Instruction for Improved Student Learning

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Abstract— **The objective of this research is to understand the contribution of technology and the principles of cognitive science employed in the class room to student learning. To this end, quantitative investigations were made in which courses were taught using (a) the traditional lecturing approach, (b) technology-based instruction and (c) intervention-based instruction. The 1st approach involved use of a standard white board to write and explain the concepts. In the 2nd method, the concepts were taught using an iPad-based instruction system. In the 3rd approach, key principles of cognitive science that are conducive to learning and long term retention were integrated into the teaching practice. As in the 2nd approach, an iPad-based system was used to deliver the lectures. All the methods were employed in an undergraduate mathematics course taught for the 2nd year engineering students. It was found that compared to the traditional lecturing approach, students were more receptive to technology-based instruction. The improved student learning was reflected in their performance in the tests. This improved performance of the students could be attributed to the *effective* delivery of the material in the classroom. It was also found that this improvement in student learning can be significantly enhanced via the intervention-based instruction. Specifically, it was found that by revisiting the topics taught earlier in the course and indulging the students in retrieval-based practice, the concepts were reinforced and helped students retain the material for a longer duration.**

Keywords—Cognitive science, Technology, Learning;

I. INTRODUCTION (*HEADING 1*)

Improving the quality of education has become a global challenge. In particular, there is a lot of focus on effective teaching and learning, and long term retention of the concepts taught to the students. Wage et al. [1] found that students in traditional lecture setting only master about 20% of the course's concepts that were taught. To this end, several investigations have focused on identifying the optimal approach to deliver lectures and enhance student learning.

Numerous researchers have shown that active and co-operative learning can significantly improve student learning, example [2, 3]. Some investigations have advocated the use of computer-based active instruction to enhance student learning [4, 5]. However, these approaches can either be too expensive [5] and/or place an enormous amount of work load on the instructors [6].

More recently, studies have used the principles of cognitive science to deliver lectures and have found success in improving student learning and retention [7, 8]. In this work, we combine the principles of cognitive science with technology and study their effect on student learning and long-term retention in an undergraduate course in mathematics for engineering students.

The specific details of the study including the course, materials, data collection and analysis procedures, are described in the Sec. II. The results found from the analysis of the data are discussed in Sec. III and pertinent conclusions are drawn in Sec. IV.

II. METHODS

The study was conducted in an undergraduate course on *Ordinary Differential Equations* (ODE) taught over a period of one term. 56 students in the first section (control section) were taught the course using the standard lecture format. 35 students in the second section (experimental section) received the technology based instruction. In addition to using technology to deliver the course material, during the 7th and 8th week of the course, an intervention strategy was employed in the experimental section to revisit the topics taught in Weeks 5 and 6.

A. *Course Design*

Student performance in the course in both sections was evaluated using four term tests and a final exam. The terms tests were administered immediately after the predetermined set of topics for the respective tests were taught in the class. In Weeks 7 and 8, the students in the experimental section were taught using an intervention strategy. This approach involved the use of the key principles of cognitive science, namely, Reinforcement, Spacing and Feedback. The motivation behind the integration of these principles in the intervention strategy is their positive effect on learning and long-term retention of the material, which are as follows: (a) *Reinforcement*: By repeatedly recalling the concepts from the memory, the information is more permanently stored in the memory. (b) *Spacing*: To aid the retention of the material for a longer duration of time, the material must be practiced over a longer span of time. (c) *Instant Feedback*: An immediate corrective feedback can help in better understanding of the material more effectively.

In contrast to this, in the control section, no such intervention-based learning was employed and the material was taught using the standard lecturing format.

B. Materials

Students in both sections were taught the same material. Specifically, the course focused on the methods of solving ODEs as well as the applications of ODE in problems involving physics. The set topics of the 4 term tests given to the students in both sections are summarized as:

Test 1: (a) **Integration**: Improper, Double and Triple integrals. (b) **Differentiation**: Chain rule, Implicit, Higher order partial differentials.

Test 2: (a) **Solution of ODE**: Separation of variables, Bernoulli equation, Exact differential equation, Initial value problems, Reducible second order differential eqn.

Test 3: (a) **Applications**: Growth & decay, radioactive disintegration, Newton's Law, Torricelli's law, chemical mixtures and law of mass action.

Test 4: (a) **Solution of ODE:** Characteristic equation, Variation of parameters, Undetermined coefficients, Inverse operators, Euler's method.

Each test was for a duration of one hour. All the tests were equally weighted towards the final grade of the student. The first two tests had around 6 questions each whereas 3rd and the 4th test had 4 questions each. The final exam was comprehensive and was for a duration of 3 hours. There were about 12 to 13 question, some with multiple parts. In addition to the topics in the 4 tests, 2 additional topics that were taught after the 4th test, namely, Applications to mechanical systems, and Simultaneous differential equations, were also included in the final exam.

C. Procedure

For the students in the control section, all the topics were taught by first explaining the concepts and subsequently solving a few examples on the white board during the in-class instruction period. At the end of each topic, the students were provided with problem sets for practice outside the classroom. The students were encouraged to seek assistance if needed either during posted office ours or by making appointments.

For the students in the experimental section, in an almost identical classroom, the topics were taught in the same manner as in the control section. However, instead of using a white board, an iPad-based projection system was used to project the instructor writing on four large screens in the front of the classroom. As in the control section, the students were provided with the same problem sets to practice outside the classroom and were encouraged to seek assistance if needed.

In addition to this, the intervention strategy incorporating the three key principles outlined in Sec. II (A) was employed to teach the topics pertinent to Test 3 to students in the experimental section. Specifically, the students were asked to solve a practice problem set containing 13 questions in the class. The problems were based on the topic 'Applications of Differential Equations', taught in Weeks 5 and 6. In doing so, the students were split into groups of 3 or 4 and each group was asked to solve a subset of these problems independently within an hour. The students were encouraged to discuss the solution approach within their respective group. Additionally, the instructor was also available for them to seek clarifications or intermittent feedback. Thus, by the end of the one hour work period, every student in the class had arrived at the correct solution and had a good understanding of the solution methodology.

The 4 tests were administered after finishing the respective topics outlined in Sec. II (B). The questions on the tests can be broadly classified into two types:

Type A: In these questions, the differential equation (DE) was given and the students were asked to solve the DE. The students were required to associate the DE with a specific solution approach and solve it for the final solution. Thus, the students were tested for the following:

1. Their ability to relate a specific DE to an appropriate solution method,
2. Apply the solution method correctly and
3. Obtain the final solution.

Type B: The application oriented problems can be classified as the problems of this type. In these questions, a physics related application involving the principles of DE was described in words and the student was asked to solve the problem. In solving the problem, the student had to:

1. Formulate the DE.
2. State the initial conditions.
3. Relate the DE to an appropriate solution method.
4. Apply the solution method correctly and
5. Obtain the final solution.

Clearly, the questions of this type are more challenging than the question of Type A. While tests 1, 2 and 4 had questions of Type A alone, the 3rd test was purely on applications of DE, and hence had only questions of Type B.

III. RESULTS AND DISCUSSIONS

A. Term Tests

The performance of the students in the 4 tests are summarized in Table 1 and the average scores of the students in these tests are shown in Fig. 1. As seen in this figure, in all but the 4th test, the performance of the experimental section is better.

In general, in either section, the student performance in the 2nd test is the least. This is because in this test the students were tested on Type A problems that required the students to correctly choose a single method from a pool of solution approaches to solve the DE. Given that the students would require an enormous amount of practice to perform well, and the short time interval between the completion of the topics and the test, their scores are expected to be low.

Comparing the results of the first two tests from the two sections, it is found that in the 1st test, the experimental section has a class average that is more than 10% higher than the control section. On the other hand, in the 2nd test, this difference shrinks to 5%. In both tests, the better performance of the experimental section can be attributed to the following:

1. By using an iPad-based projection system, the instructors writing were projected on 4 large screens in the front of the class. As a result, the students in the entire classroom had a clear view and were able to take notes more effectively. On the other hand, in the control section the instructor used a single white board on the front wall and positioned closer to one end of the wall. This may have introduced some hindrance to the learning process of the students sitting at the far end of the classroom. Specifically, the struggle for accurate note taking is likely to negatively impact that in-class attention and thereby their learning.

2. In the experimental section, the instructor was continuously facing the students throughout the duration of the lecture. As a result, it was easy to gauge the student perception and adjust the lecture delivery almost instantaneously. This has a positive effect on the learning of the students.

Table I. Test results from the control (1) and experimental (2) section.

	Test 1		Test 2		Test 3		Test 4	
Section	1	2	1	2	1	2	1	2
Average	52	63	41	46	49	77	52	50
Std. Dev.	21	17	20	18	23	18	18	23
Effect Size	**0.56**		**0.26**		**1.32**		**-0.1**	

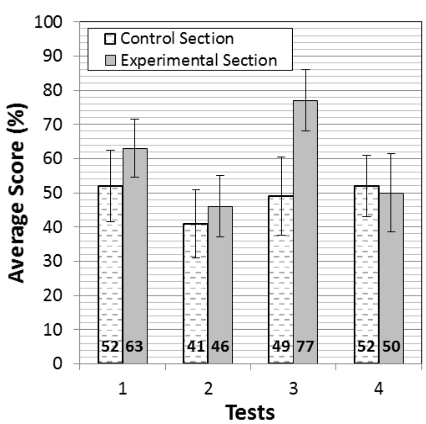

Fig. 1. Average score in the four tests indicated at the bottom of each bar in the graph.

In the 3rd test, the experimental section's average score was 28% higher than the control section. While there is an improvement in the performance of the students due to the use of technology, a significant increase in the demonstration of learning in the experimental section can be attributed to the use of intervention strategy. Put differently, the small changes to the standard teaching practice resulted in a significant learning and retention of the course material.

An important point to note with respect to this test is that the topics covered in this test are considered the most difficult. This is because all the 4 questions on this test were of Type B. As described in Sec. II(C), to solve these problems, the students were required to formulate the appropriate DE with the initial conditions before applying the pertinent solution approach to obtain the final solution.

In the fourth test, the performance of either section is similar. This was expected is most likely due to the fact that this test was within 2 weeks of the final exam period and the students had numerous other deadlines from the other courses. It must be pointed out that the intervention strategy was applied only for the topics pertaining to the 3rd test.

B. *Effect size*

To obtain a quantitative estimate of the influence of the factors varied in the experimental section, an effect size is calculated as

$$d = \frac{\bar{x}_1 - \bar{x}_2}{s}, \tag{1}$$

where d is the effect size, $\bar{x}_1$ and $\bar{x}_2$ are the average of the test score in the control and experimental section, respectively. s is the pooled standard deviation that is calculated as

$$s = \sqrt{\frac{(n_1 - 1)s_1^2 - (n_2 - 1)s_2^2}{n_1 + n_2 - 2}}, \tag{2}$$

where n_i and s_i are the number of and the standard deviation of the i^{th} section, respectively.

As summarized in Table 1, integrating technology-based lecture delivery in the curriculum results in an average effect size of about 0.41 between the first 2 tests. On the other hand, by employing the principles of cognitive science in the classroom and making small adjustments in the teaching practice, an effect size of 1.36 is realized. This indicates a significant improvement in the learning and retention of the concepts taught in the classroom. It must be noted that this value reported here matches closely with the findings of Bloom [9] in which he reported an effect size of about 1.20 when strategies to reinforce concepts are used in the classroom.

C. *Final Exam*

In this section, we explore the long term retention of concepts taught using the intervention technique in the experimental section. For this, 3 questions are chosen from the final exam. The first question (Q1) was taught in Week 5 and an intervention strategy was employed in Weeks 7 and 8. The second question (Q2) was a Type A question that was based on a topic taught in Week 11. The third question (Q3) was a Type B question that was from a topic taught in Week 13. Thus, compared to Q1, the other two question were relatively recent.

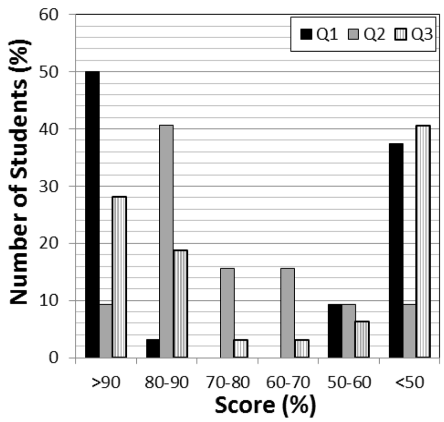

Fig. 2. Student scores in 3 questions from the final exam of the experimental section.

The results from the 3 questions on the final exam are shown in Fig. 2. As seen in this figure, nearly 50% of the students in the class scored more than 90% in solving Q1. On the other hand, almost 38% of the class failed in this question, whereas about 10% are in the range of 50-60%. In fact, from the graph it appears that the student either retains the solution methodology completely or is unable to solve the problem.

Such a trend is not observed in Q3 that is also a Type B question. Unlike Q1, this was taught very close to the final exam. Also, there was no intervention strategy employed in this topic. While there is a clear distribution of the students over a range of scores for this question, nearly 41% of the students score less than 50% on this question. This is still marginally higher than Q1. Nevertheless, one can argue that this is within some error limits.

In case of Q2, once again we observe a wide distribution of scores with a majority of them (41%) clustered around 80-90%. More than 90% of the students scored over 50% in this question. This is because (i) the question is relatively easy and (ii) it was taught much closer to the final exam. As a result, a majority of the students are able to recall the material during the examination.

On comparing the performance of the students in the three question we find that nearly 50% of the students are able to retain and recall Q1, the oldest topic, with a score of more than 90% on this question. The number of students able to do this in Q2 and Q3 are 9% and 28%, respectively. Put differently, the use of a simple intervention strategy like the one done in this study can significantly enhance the student learning and long-term retention.

IV. SUMMARY & CONCLUSIONS

In this study, the effects of use of technology and the principles of cognitive science in classroom on the student learning are explored. Specifically, a quantitative investigation was made in which a 2nd year undergraduate course in the area of ODE was taught for engineering students using either (a) the traditional lecturing approach, or (b) technology-based instruction and (c) technology and intervention-based instruction. The 1st approach involved use of a standard white board to write and explain the concepts. In the 2nd method, the concepts were taught using an iPad-based instruction in which the instructor explained concepts on an iPad that was projected on 4 large screens in the classroom. In the 3rd approach, in addition to the use of technology, the principles of cognitive science that are conducive to learning and long-term retention of the topics were combined. It was found that compared to the traditional lecturing approach, students were more receptive to technology-based instruction. The improved student learning was reflected in their performance in the tests. This improved performance (effect size of approximately 0.41) of the students could be attributed to the effective delivery of the material in the classroom. However, a significant increase in students' performance in the test (effect size of approximately 1.36) was evident with the use of intervention-based instruction. It was found that by revisiting the topics taught earlier in the course and indulging the students in retrieval-based practice, the concepts were reinforced and helped students retain the material for a longer duration.

It can be concluded that student learning can be significantly affected by employing technology-based instruction for effective delivery of the material and combining it with intervention-based teaching for retrieval, understanding and long-term retention of the material. The latter has a more significant positive impact on the student learning outcomes.

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Tuning Mechanical Engineering Higher Education in Africa toward Unified Quality and Accreditation

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***Abstract*—This article uses the "Tuning" methodology that is being successfully employed in harmonizing higher education in Europe, Latin America and Russia for harmonizing undergraduate mechanical engineering programmes in Africa. Unlike Europe and the USA, Africa lacks a unified engineering accreditation organization. As such there is limited mutual recognition of university degrees and very little academic integration among its countries. In this paper academics from 11 African universities examine the structure of mechanical engineering programmes including content structure and degrees awarded, develop competences by engaging stakeholder groups through a survey questionnaire, and abstract a mechanical engineering meta-profile. Lessons are drawn from Tuning projects in other regions, especially Europe, and from well-established accreditation regimes such as the American Accreditation Board for Engineering and Technology and the European Network for Accreditation in Engineering Education to guide the evolution of a similar structure for Africa. The overall aim is to collaboratively contribute to reforming and harmonizing mechanical engineering higher education to make it more responsive to Africa's developmental needs. Results so far indicate not only feasibility but also strong promise for establishing compatible academic structures and reference standards across Africa which could facilitate student and staff mobility while enhancing greater cooperation among African academic institutions and between them and those in the rest of the world. Eighteen generic competences and nineteen mechanical engineering-specific competences are developed, analyzed and synergized to form a meta-profile to serve as basis for curriculum enhancement for future unified accreditation.**

Keywords*—Mechanical Engineering, Competences, Meta-profile, Accreditation;

I. INTRODUCTION

In the last decade, higher education in Africa has witnessed a transformation influenced and catalysed by both internal intricacies and external dynamics. One transformation initiative which links institutional, national, regional, continental and international endeavours is the Higher Education tuning initiative, which started in the year 2000 in Europe following the Bologna Process. It aims to achieve: a system of easily readable and comparable degrees, undergraduate degree-relevance to the European labour market, establishment of a system of credits, promotion of mobility for students, teachers, and researchers, promotion of co-operation in quality assurance with regards to curricular development, and integrated programmes of study and research.[1] From Europe Tuning moved on to Latin America, Russia, Georgia, the United States, and recently to Australia, India, China, and Africa, where the African Higher Education Harmonisation and Tuning Project, which is part of an African Union - European Union strategic partnership initiative[2], is now underway. So far more than 2000 universities in over 60 countries around the world have employed the methodology to reform their higher education systems.[3]

The Tuning methodology itself is an interactive process in which academics develop quality curricula and learning standards for students by evolving generic and subject specific competencies in consultation with employers, students, graduates, peers and other stakeholders involved in higher education. The importance of Tuning as an instrument for systematic Higher Education reform and quality enhancement has been reported in the literature[4]. Specific success cases such as those relating to using the methodology to determine student workload and degree profiles in Latin America have also been discussed in the literature[5].

Unlike Europe and the USA, Africa lacks a unified engineering higher education accreditation organization, although it is very much in need of such an oversight structure due to the presence of sharply disparate higher education systems among its 54 countries, a legacy of its colonial history. As a result there is limited mutual recognition of

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university degrees among countries, which limits student and staff mobility, research, and general academic integration, among others. To address these structural problems the African Union Commission, in partnership with the European Commission under the Joint Africa-EU Strategic Action Plan 2011-2013, launched the policy of Harmonization and Tuning of Higher Education in Africa, as a core project in the implementation of continent-wide initiatives to help harmonize, reform, and enhance quality in higher education. As part of this initiative Mechanical Engineering (ME) is one of five subject areas whose harmonization is being piloted in eleven Africa countries. The other four disciplines are: Civil Engineering, Medicine, Agriculture, and Teacher Education. Even though the primary focus of this study is on mechanical engineering education, generic issues that also affect all the other disciplines have been discussed.

II. METHODOLOGY

The main steps followed in this study are outlined below.

i. Step 1 - Defining Mechanical Engineering (ME) and brainstorming on the suitable professional profile of an ME graduate;
ii. Step 2 - evolution of an initial set of generic and ME subject-specific graduate competencies;
iii. Step 3 – Defining stakeholder groups, administering survey questionnaire and interviews in consultation with four stakeholder groups: academics, employers, students, and graduates. These were asked to indicate the level of "importance" and the level of "achievement" of each generic and subject specific competence and to rank all competencies in a descending order of importance on a scale of 1 to 4 as follows: strong = 4/4, moderate = 3/4, weak = 2/4, none = 1/4;
   A total of four thousand three hundred and twenty three (4323) respondents returned the generic competencies questionnaire, of which 579 came from ME stakeholders; and a total of 3812 respondents provided answers to the subject specific questionnaires of whom 494 (13%) are from mechanical engineering. Sixty universities across Africa were involved in the survey;
iv. Step 4 –Abstraction of an ME meta-profile, based on a reordering and classification of the competences and building of reference points;

Each of the above steps involved four face-to-face meeting sessions of extensive deliberations among representatives of the participating African Universities. Issues related to methods of teaching, learning and assessment and quality enhancement were not covered by the study.

III. RESULTS AND ANALYSIS

A. Evolution of Competencies

Working in collaboration with the four other subject-area groups, 18 generic competences (Table I) were agreed upon as representing the characteristics desired in a holder of a first (Bachelor’s) degree in any discipline.

Table I. List of generic competencies (for all disciplines)

1. Ability for conceptual thinking, analysis and synthesis
2. Professionalism, ethical values and commitment to UBUNTU (respect for the well-being and dignity of fellow human beings)
3. Capacity for critical evaluation and self-awareness
4. Ability to translate knowledge into practice
5. Objective decision making and practical cost effective problem solving
6. Capacity to use innovative and appropriate technologies
7. Ability to communicate effectively in official/ national and local language
8. Ability to learn to learn and capacity for lifelong learning
9. Flexibility, adaptability and ability to anticipate and respond to new situations
10. Ability for creative and innovative thinking
11. Leadership, management and team work skills
12. Communication and interpersonal skills
13. Environmental and economic consciousness
14. Ability to work in an intra and intercultural and/or international context
15. Ability to work independently
16. Ability to evaluate, review and enhance quality
17. Self-confidence, entrepreneurial spirit and skills
18. Commitment to preserve and to add value to the African identity and cultural heritage

Next, nineteen ME-specific competencies (Table II) were developed by the ME group. Earlier Tuning projects (Europe, Latin America and Russia) did not include mechanical engineering, so the ME group used, as its key institutional reference, the set of competences for mechanical engineering training employed by the American National Accreditation Board for Engineering and Technology (ABET)[6], and the Egyptian National Reference Standards (NARS)[7] issued in 2009.

Table II. List of ME-specific competencies

1. Ability to apply knowledge of the basic and applied sciences of mechanical engineering.
2. Ability to identify, evaluate and implement the most appropriate technologies for the context in hand.
3. Capacity to create, innovate and contribute to technological development.
4. Capacity to conceive, analyze, design and manufacture mechanical products and systems
5. Skills in planning and executing mechanical engineering projects.
6. Capacity to supervise, inspect and monitor mechanical engineering systems.
7. Capacity to operate, maintain and rehabilitate mechanical engineering systems.
8. Skills in evaluating the environmental and socio-economic impact of mechanical projects.

9. Capacity to model and simulate mechanical engineering systems and processes.
10. Skills in selecting, mobilizing and administering material resources, tools and equipment cost-effectively
11. Capacity to integrate legal, economic and financial aspects in decision-making in mechanical engineering projects.
12. Capacity for spatial abstraction, graphic representation and engineering drawings.
13. Providing mechanical engineering solutions to societal problems for sustainable development.
14. Skills in safety and risk management in mechanical engineering systems
15. Skills in using information technologies, software and tools for mechanical engineering.
16. Capacity to interact with multidisciplinary groups towards developing integrated solutions.
17. Skills in employing quality control techniques in managing materials, products, resources and services.
18. Capacity to conduct life cycle assessment for products and systems
19. Capacity to employ mechanical engineering skills to transform local natural resources into products or services through value addition.

B. Analysis Procedure

Analyses of data were conducted using the following procedure:

i. The competencies were ordered in a descending order of importance
ii. Levels of achievement corresponding to (i) were recorded,
iii. The level of importance (i) and the corresponding level of achievement (ii) identified the current gaps.
iv. Ranking of the eighteen (18) generic competencies was carried out.

C. Consultation Results

The above analysis yielded the following observations in regard the generic competencies:

i. Levels of importance were much higher than levels of achievement, with the highest gaps occurring in competencies related to ability to use innovative technologies, and for creative and innovative thinking,
ii. Conceptual thinking and translating knowledge into practice top the list of competences in terms of importance and ranking, while competencies related to environmental and economic consciousness, and the ability to work in regional and international contexts were placed at the bottom of the lists by all groups,
iii. For ME graduates the highest gaps were in the areas of entrepreneurial talent and self-confidence.

Analysis of data for the ME specific competencies resulted in the following findings:

i. As with generic competences, levels of achievement were scored lower than levels of importance by all stakeholders, with competences related to efficient use of natural resources, and working in multi-disciplinary groups showing the highest gaps.
ii. The most highly ranked competencies were those associated with ability to apply knowledge of the basic and applied ME sciences, capacity to conceive, design, analyze and manufacture products and systems.
iii. Creation of technology and its innovation is ranked high by all stakeholders, except employers.
iv. Competencies related to safety and risk assessment, quality control, and life cycle assessment are ranked very low by almost all stakeholders.

D. Profile Development

A review of ME degree profiles and learning outcomes from the participating universities led to a consensus on recommended proportions of core elements of a ME curriculum. These are: Basic and applied Sciences of Mechanical Engineering (40%); Design (20%); Analysis (20%); and Practice (20%). Qualitatively, these are in agreement with the curriculum requirements of the US-based ABET[6], which emphasizes the application of principles of engineering, basic science, and mathematics to model, analyze, design, and realize physical systems or processes.

Next came the development of the curriculum profile. Based on the earlier rankings of competencies, clusters were formed, namely: (1) Core and Knowledge, (2) Skills, and (3) Attitudes clusters, constituted in terms of cognitive attributes - the drivers and the driven - of both specific and generic competencies. Broadly, this suggests that specific and generic competencies aid and reinforce each other.

A synergy among the competency clusters in delivering the ME core functions became evident. An analysis with regard to “importance”, “achievement”, and “ranking” of all competences led to the development of a meta-profile of Mechanical Engineering (Figure 1). In the figure the core content clustered with the generic and subject specific competencies, gives the programme its specific identity. The core is serviced by 9 apexes of three triangles. The 6 inner apexes represent ME Sciences, Innovation & Creativity, Quality, Managerial and Behavioral skills, Communication and Interpersonal skills, Professionalism and Ethics while the 3 outer apexes represent Community Engagement, Entrepreneurial skills and Sustainability. The competency groups identifying the apexes in Figure 1 are determined according to the following code:

Final Rank - Type: (G or S) - Original Order

Thus, a competence coded as 08-G-02 means: the generic competence whose original order is (02) and final ranking is (08). From the original list, this competence is readily identified as: Professionalism, ethical values and commitment to UBUNTU (respect for the well-being and dignity of fellow human beings).

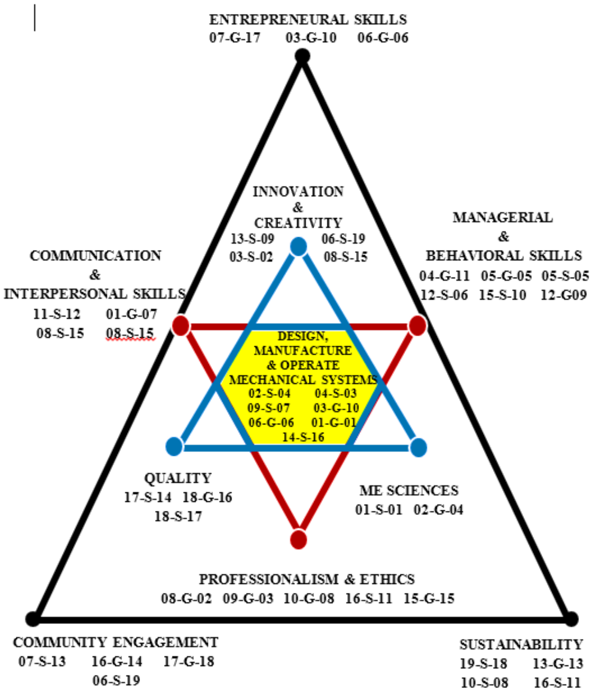

Fig. 1 Mechanical Engineering meta-profile

IV. Discussion

The analyses so far point to a number of important general patterns: Levels of importance attached to competencies are much higher than the respective extents of achievement of those competencies, as seen by stakeholders. A comparison of the developed meta-profile with existing degree profiles yielded the following observations:

i. There exists a remarkable coincidence between the developed meta-profile and existing degree profiles especially in the ME core functions.
ii. However, in other areas there is poor correlation between the two, with existing degree profiles lacking in emphasis regarding innovation and creativity, managerial and behavioral skills and quality.
iii. Further, existing degree profiles betray a lack of emphasis on professional ethics, community engagement, environmental, social and economic impact assessment, product life cycle assessment and provision of ME solutions towards sustainable development.
iv. Some existing degree programmes retain aspects of legal and financial issues, but in others they are totally absent.
v. The developed profile comes out as better than the existing profiles in that it highlights societal expectations upon a ME graduate in a more forceful way.

While some of the responses mirror the low level of technological development in the continent, others clearly are a pointer to the reform needs of current curricula. Here, Africa could learn from the Quality Assurance (QA) experiences jurisdictions including Europe, where a “European QA Register of Higher Education”[1], and “Standards and Guidelines for QA in the European Higher Education Area”[8] have been established. But as the practice of “accreditation” increases throughout the world[1] especially in subjects that lead to a “profession”, some studies[2] have raised caveats as to whether the expected skills can be effectively imparted and evaluated[9], since QA often tends to assess more the “process” than the “contents” of the education[1].

V. Concluding Remarks and Recommendations

African systems of higher education are diverse, a result of various historical legacies. The Tuning process gives Africa an instrument which could create opportunities for harmonizing academic structures to facilitate mobility, while enhancing higher education curricula and cooperation among African academic institutions. In conclusion, 18 generic competences and 19 ME-specific competences have been synergized to form a meta-profile towards curriculum reform.

Future work will include: deepening the process by defining detailed learning objectives and outcomes, carrying out gap analysis between existing curricula and the developed meta-profile, developing generic competencies for all engineering disciplines, subjecting the meta-profile to a stakeholder validation process, disseminating findings to a wider audience and addressing implementation challenges.

Acknowledgment

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Addressing Assessment and Grading in Engineering Education: A Case Study of Policies and Practices

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***Abstract*—Assessment and grading of student work are of considerable interest inside and outside of academic institutions. It is therefore in the interest of all stakeholders that assessment and grading are valid, reliable and fair. However, longstanding investigations have demonstrated that variations and significant discrepancies do occur when assessors design and apply assessment rubrics and criteria without careful thought as to the consequences. This study demonstrates an instance of unintended consequences in grading judgments in a third-year engineering course in one Norwegian university. Overall achievement was measured by aggregate scores on a scale ranging from 1-100 with 40 as the minimum pass threshold. Based on this rule, the initial pass rate was 80. Unfortunately, the application of aggregate scores is intrinsically fully compensatory, hiding strengths as well as weaknesses. By requiring a minimum of 40 points in each of the two sub-sections of the course, the pass rate was halved. Raising the minimum score level from 40 to 50 in each of the two major sections of the course would reduce the pass rate from 40 to 13, which is alarming for the students and for the course. The need for change is evident in this course, and the study concludes with suggestions for improvements to validity and reliability.**

Keywords—Criterion-based assessment, scores, grade integrity

I. Introduction

Assessment and grading of student work are activities of considerable interest in higher education generally, and in engineering education in particular. Interest is evident wherever we consider assessment at subject or at department level, at institutional level or across educational systems at national or international level. The purpose of this study is to address issues of a fundamental nature, potentially with more general practical implications.

Teachers in engineering education have experienced high levels of choice and freedom in assessment, operating largely outside of national testing systems and without the type of strict measurement models that has been implemented in other educational settings. To some extent, assessment and grading still take place behind closed doors; however, there have been changes to levels of freedom and choice. Increased frequency in appeals against grades prompts the question as to whether assessment procedures are rigorous and fair. There is now widespread pressure from society at large to get assessment 'right'.

This paper reports on an in-depth study of assessment and grading practices in a third/fourth year course in engineering education. The approach described here is at the level of concepts and underpinning principles rather than quantitative outcomes. My research questions relate to the implementation of criterion-based assessment, and investigate the extent to which practices can be deemed reliable and fair: Questions are

- In what way is the principle of 'criterion-based' assessment implemented in the course?
- What would be the effect if the markers interpreted the same assessment principle differently?

II. Context and Theoretical Approach

Assessment and grading are at the heart of the students' academic experience and may impact their future academic and employment opportunities. For assessors, assessment is the point at which they can ensure that intended learning outcomes have been achieved. Much effort has therefore been invested into making assessment formats relevant, transparent and fair. A key measure has been the adoption of a criterion-based assessment framework accompanied with quality assurance procedures, including external reviews. These structures are typical features of what has been termed the 'accountability paradigm' with an emphasis on accrediting explicit learning outcomes, on constructive alignment and on transparency in grading criteria and assessment framework [1].

One frequently quoted commentator, Sadler, holds out the goal that an awarded grade should be 'strictly commensurate with the quality, breadth and depth of a student's performance' [2]. To succeed in this endeavor, a criterion-based approach sounds attractive. In theory, using criteria implies the application of fixed anchor points rather than students being assessed in comparison with one another. However, institutions vary in their interpretation of this grading principle, and rather diverse practices have been identified under the same heading. Researching a range of institutions, Sadler has identified four different interpretations of 'criterion-based' assessment [3]:

- Grading Model 1: Achievement of course objectives. (The marker makes use of course objectives as reference points for scoring and grading).
- Grading Model 2: Overall achievement as measured by score totals. (The marker assigns scores to sub-tasks upon which an aggregate score is calculated).
- Grading Model 3: Grades reflecting patterns of achievement. (Assumes attention to performance levels

in different parts of an examination, not only the total score).

- Grading Model 4: Specified qualitative criteria or attributes. (Allows the marker to pay attention to generic attributes, such as presentation, organization or relevance).

While the above models demonstrate various ways in which criterion-based assessment has been practiced, the focus in this study is on Grading Model 2 and Grading Model 3. The purpose is to demonstrate effects on grades that can be attributed to the consequences of choosing one or the other model. In the first model, achievement is measured against explicit learning objectives, meaning the assessor is judging whether or not the item being judged shows that the student has achieved the stated learning. In contrast, the second model aggregates scores with the final result (usually denoted as a grade) reflecting the points scored reflection the points scored rather than the learning recognized. Model 3 differs from the previous ones in that it enables attention to the range and variation in achievements, operating both at the level of the individual student and across a cohort. Engineering in particular is often very interested in this pattern. Evidence of some minimum level of performance across the spectrum of tasks might be in the interest of the institution and increase the candidate's future career opportunities. In contrast to a focus on patterns (Model 3), Grading Model 2 is fully compensatory for patterns exhibited in sub-scores, meaning that a student can do very poorly in one section and yet achieve a positive outcome if he or she does very well in one or more other sections. The fourth model, by looking specifically at selected attributes or skills, can cover a range of generic attributes mentioned in institutions' mission statements, but will not be pursued further in this study. In summary, the review under discussion draws upon Sadler's models for judging overall achievement and for judging patterns of achievement.

Turning to the course under review: Two professors taught the course, dividing the task into two parts of equal weighting. Assessment was by final examination; it lasted four hours and consisted of 14 questions, seven linked to each of the two sub-sections. The large number of questions enabled substantial coverage, with an emphasis on theoretical as well as on applications of methods and principles. Examination questions were designed individually by the professors, working independently, and would be marked using a range from 1-100. Scores were added into final aggregate scores, after which a conversion scale was used to turn numerals into grades from A – F, with E as the baseline grade for a pass.

Table 1 Score ranges for turning raw scores into letter grades

A	B	C	D	E	F
100 - 90	89 - 80	79 - 60	59 - 50	49 - 40	39 - 0

III. Data and Analysis

Grade descriptors were available to support the implementation of criterion-based assessment, but these were not seriously considered by the professors. They practiced the principle outlined in Grading Model 2 (grades reflecting patterns of achievement). Aggregate scores were calculated and grades assigned according to score ranges, as displayed in Table 2.

Table 2 Students awarded a 'pass' grade based on aggregate scores of minimum 40 points (N=30)

	Professor		External Examiner		Total	
≥ 40 %	**N**	**Per cent**	**N**	**Per cent**	**N**	**Per cent**
Part 1	29	96.7 %	26	86.7 %	28	93.3 %
Part 2	15	50.0 %	8	26.7 %	12	40.0 %
Total	25	83.3 %	20	66.7 %	24	80.0 %

Table 2 shows that the candidates' pass rate is higher in Part 1 than in Part 2 of the course, and that there is a big discrepancy in terms of pass rate between the assessors, especially in Part 2. Since the score combination rule is intrinsically compensatory, 80 % (24/30) of all candidates still passed the course despite the fact that the calculated pass rate in Part 2 was only 40 % on a scale of 100. The rule for combining sub-scores by adding them together into aggregate scores produces anomalies in the distribution of grades. Generally, superior performance in Part 1 compensated for weak performance in Part 2, and real patterns of strengths and weaknesses were lost. Score patterns are displayed in Figure 1 with a correlation of (r=0.67).

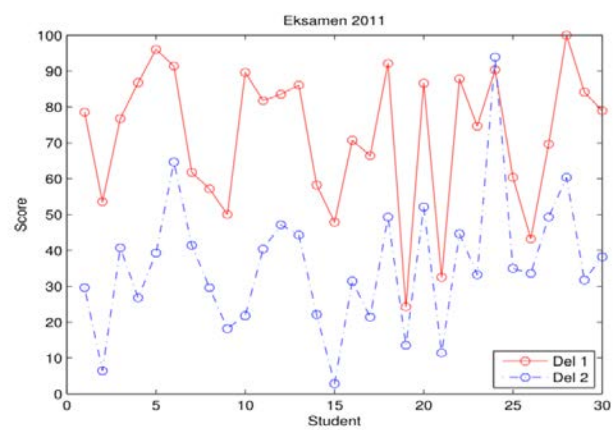

Figure 1 Chart displaying aggregate scores for all candidates in Part 1 and Part 2 (N=30)

I now take the opportunity to manipulate scores to examine effects of a different score combination rule based on Grading Model 3 (Table 3). This assumes a minimum score of 40 points (out of 100) in each part to ensure an acceptable level of achievement in major parts of the curriculum. A single change, here a hypothetical requirement of 40 points in both sections of the course, would have the effect that the percentage of students passing the course would drop from 80 % (24/30) to 40 % (12/30). This would have dramatic consequences - for the reputation of the course and for students' career opportunities.

Further hypothetical adjustments have even more alarming consequences: if one raised the minimum pass level in both Part 1 and Part 2 from 40 to 50 points, then only four students (13.3 %) would pass; raising the minimum pass level to 60 points would see only three students out of 30 (10 %) passing the course (see Table 3).

Table 3 Hypothetical scenarios when pass thresholds differ for each of the two major sections of the course (N=30)

Threshold	Professor		Ext. Examiner		Total	
	N	**Per cent**	**N**	**Per cent**	**N**	**Per cent**
≥ 40 %	15	50.0 %	8	26.7 %	12	40.0 %
≥ 50 %	10	33.3 %	3	10.0 %	4	13.3 %
≥ 60 %	4	13.3 %	1	0.03 %	3	10.0 %

The discrepancy between the assessors' grading is a striking feature, and a matter of concern in this case. Since the purpose of the external examiner is to ensure valid and reliable grading, efforts have to be made to better align grading practices.

IV. Discussion and conclusion

Data presented in this study are concerning from several perspectives. First, if the purpose of grades is to give a true representation of achievement, then applying a combination rule which accumulates sub-scores produced anomalies and violates a requirement stated by John Biggs: 'If a topic or task is important enough to be in the curriculum, it should be passed at some minimum level of understanding' [4]. At its most extreme, it would be possible for a student to pass with a score of 100% on one section and 0 % on another yet be accredited for achieving the learning outcomes stated in the course documentation. The problem here is that students may receive their diploma on false grounds. Such practice violates the principle of grade integrity, and adds to the risk of people committing mistakes in the execution of professional tasks.

At one level, simply applying Grading Model 3, described above (i.e. attention to patterns of achievement), the result would be greater reliability. However, if grades are to truly and accurately reflect students' achievements, then other changes would be needed. Some of these are practical, such as: rethinking the design of exam tasks and adjusting the level of difficulty. Other changes are more theoretical and delve into the nature and purpose of the course. They include: checking the balance of conceptual versus computational learning objectives, investigating whether the curriculum is promoting surface rather than deep learning [5], and checking whether the demands of constructive alignment are met [6].

In this study, the need for change is evident. One place to start would be by aligning learning objectives and exam requirements in the two major sections of the course. An analysis of exam questions indicates that tacit assumptions probably were not shared or discussed between teachers. Tasks encountered by students therefore to a large extent reflect the professors' 'private' expectations. Questions in Part 1 featured mostly methodological and computational items begging for 'correct' answers, while Part 2 to a greater extent emphasized conceptual understanding. It is well known that students may be successful in performing manipulations of numbers, while not achieving higher cognitive levels aimed at 'deep learning'. Rethinking course design would have the effect of promoting consistency between intended outcomes, learning material, what is taught and assessed. This study has demonstrated the need for practices that better reflect actual learning outcomes.

Agreeing on what is to be achieved is a key requirement in course design, as is knowledge of assessment criteria and standards. In the course under scrutiny, learning objectives were only presented as one-way messages, and implications in terms of content, learning activities and assessment were not subsequently acknowledged or implemented. Individualized practices prevailed and the consequences, here in the form of students' achievements, were not reflected in the final grades. This study has uncovered shortcomings in grading policies, as well as issues of course design generally. Task requirements in the sub-sections were not aligned, and disparities exhibited by the examiners confirm the need for re-calibration of criteria and standards. Imagined effects of greater clarity and more transparency in this area might be increased reliability in scoring and grading, as well as improved opportunities for students to work more steadily towards desired ends.

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Experiences Teaching a Capstone Design Course

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Abstract— A senior design course is offered each semester by the Department of Civil and Environmental Engineering (CEE). The course learning objectives (CLO) include mastery of teamwork, project management, professional practice, and effective oral and written communication. Students are assigned to teams that act as a consulting firm, with specialists in the areas of environmental, water resources, geotechnical, pavements, structural and transportation engineering while each team is led by a student project manager. The design project covers the multi-dimensional aspects of civil and environmental engineering, thus presenting opportunities for students to interact across and learn about interdependencies among various disciplines. The results of multi-year data on (a) how students assess their own mastery of the CLOs, (b) CLO assessment for ABET, and (c) practitioners evaluations, are documented. These direct and indirect evidences of mastery of the CLOs provide meaningful and rational feedback to gauge learning of students throughout the course.

Keywords—capstone design; course learning objectives; ABET

I. Introduction

The Department of Civil and Environmental Engineering at Michigan State University has included a capstone design course in its curriculum since 2005. The semester-long course, CE 495, is presently taken by seniors in both civil and environmental engineering programs in their last semester. Students must have completed at least two senior-level course in two different areas: environmental, geotechnical, hydrology/hydraulics, pavements, structures, and transportation. At the start of the course students are assigned to a sub-discipline or to the role of project manager. Using a lottery system, the project managers then pick their teams, which function as a consulting firm to solve a complex civil engineering problem. The lottery system helps to distribute stronger and weaker, more dedicated and less motivated students across the teams.

In order to ensure mutual interdependence and collaboration between team members, the problems are designed to be complex. Students are required to develop contracts between members along with team names and logos, and to write a letter introducing their “company” to a potential client. The lead faculty member meets weekly with project managers to help with project oversight and ensure that the team members are working well together. Students in each of the subdisciplines are guided through the course by a faculty member in that subdiscipline.

The course learning objectives have been developed as part of the ABET process and are mapped to the ABET student outcomes A-K and the professional practice student outcomes developed by the American Society of Civil Engineers.

1. Gain experience in team-based design as a specialist in one area for a multi-area project (D: teamwork)
2. Identify and explain the leadership responsibilities of the project manager and technical specialists for this project (P4: leadership)
3. Explain basic concepts of project management applicable during the design phase (P1: management)
4. Be familiar with issues of professional practice including standards of practice; their use in design; and responsibility to the client and the public trust including the environment (E: identify, formulate, and solve engineering problems)
5. Explain major issues related to professional practice as they apply to the project (J: contemporary issues)
6. Identify specific constraints imposed on a design by codes, laws, regulations, and standards of practice (K: use of techniques, skills, modern engineering tools)
7. Develop preliminary engineering design alternatives for elements of a civil engineering project (C: design a system, component, or process)
8. Include consideration of sustainability in design alternatives (S3: sustainability in design)
9. Identify elements of design that need coordination between specialty areas (P1: management)
10. Write a technical report that documents calculations used to develop design alternatives (G: effective communication)
11. Write a non-technical report to present design alternatives, their attributes, and estimated cost (G)
12. As part of a team, prepare and deliver an oral presentation suitable for a non-technical audience. (G)
13. Recognize the need to engage in lifelong learning (I: life-long learning)

II. Background

Capstone design experiences has been given considerable attention since the advent of ABET Engineering Criteria (EC) 2000, although some schools had already implemented senior design/capstone type courses by 1995 [1]. However, as a result of ABET EC 2000 Criterion 4, which required an integrative and comprehensive design project experience that included a range of realistic considerations, the capstone design course became the ideal. Capstone design courses are most often year-long efforts as shown by McKenzie et al. [1] who reported that 58% of the faculty respondents indicated that their capstone design courses were year-long projects while 31% of the projects were completed in one semester. In slightly fewer than half of the courses reported, all student design teams completed the same project in a given course [1]. The remaining completed different projects.

Labossière and Roy [2] reported on design projects at several universities, including Université de Sherbrooke, University of Delaware, the University of Wisconsin-Madison, and Purdue University. All of these projects are open-ended and require students to collaborate across subdisciplines in civil engineering. The assignment of students to teams varied across the universities; in some cases students picked their own teams and in other cases the instructor picked the teams. In one case (Purdue), membership was determined based on grades and Meyer-Briggs personality assessment. Most of the projects are infrastructure projects and as such, few will be constructed. Seattle University's capstone design course seems to be fairly unique in that the projects are fully supported by industrial sponsors who pay $5,000 to $20,000 [3]. The University of Oklahoma has a unique experience in that, while students spend their last semester in their program working on the capstone design project, the project is passed from one class to the next, with the first class completing a development master plan, followed by the completion of a design analysis and environmental assessment, then students in the third class (sequential semesters) completes a site analysis and cost evaluation, and in the fourth semester, the new group of students refine the previous designs and include details such as a detention pond, pedestrian bridge, and jogging path [4]. The incorporation of capstone design projects into the civil engineering curriculum extends beyond the US and Canada. For example, Pauzo and Muda [5] describe the capstone design course that is now included as part of the civil engineering curriculum at the Universiti Tenaga Nasional in Selangor, Malaysia.

III. SAMPLE PROJECT

For the last four semesters, the capstone project has involved the development of an area near campus. During three of these semesters, the students focused a preliminary design for an apartment complex on a ten-acre site. The structural students designed the structure and provided an architectural layout. The geotechnical students designed the foundation and a retaining wall to the east of the complex, allowing for more complete development of the site. The environmental engineering students designed a constructed wetland to treat stormwater runoff from the site. The hydrology students designed the stormwater collection system and the outfall to the river. Both hydrology and environmental students worked with the team to incorporate low impact development measures into their design. The transportation students designed underground and surface parking along with roads into and through the complex. The pavement students designed the pavements in the complex and rehabilitated the surrounding roads. In Spring 2014, we enlarged the site and had the students plan a 60-acre planned unit development (PUD), address issues related to ground and surface water quality and transportation, rehabilitate and design pavements, and design a structure with a foundation and retaining water, a water treatment facility, and a water distribution system. The students were required to review township board minutes to understand the concerns and desires of the community for the site.

IV. ANALYSIS

As part of the ABET assessment process, after the completion of each course, data are collected to assess student mastery of CLOs. This information is used to provide faculty with the feedback necessary to ensure continuous quality improvement.

A. *Professional assessment of student mastery of CLOs*

The students are assessed by professional engineers during Design Day, when the team makes a formal presentation to a panel of engineers who serve as the client and other interested parties (such as the city/township, county drain commissioner, road commission, etc.). Fig. 1 shows the variation of the mean rating by professionals between different years.

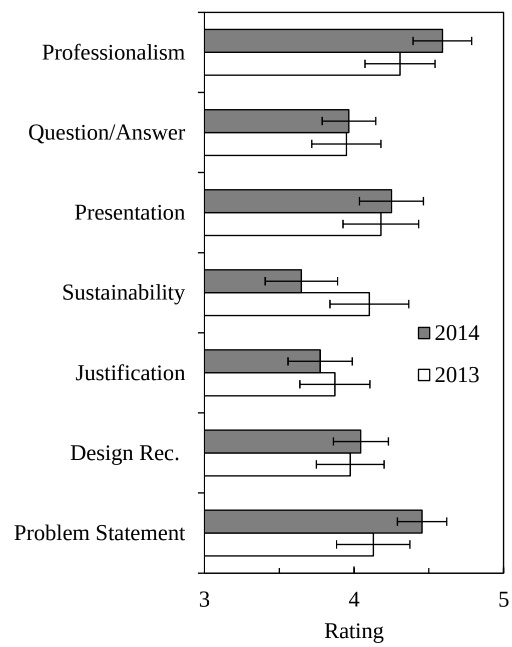


Fig. 1 Summary of professional ratings for student performance during final presentations
Note: 5 = excellent, 3 = acceptable, 1= poor

In Spring 2013, six teams (42 students) were evaluated by thirteen professionals. In Spring 2014, seven teams (49 students) were evaluated by nineteen professionals. As shown in this figure, student performance was uniformly high during both semesters. However, the professionals' ratings for the design justification and sustainability categories were consistently lower in both years. In Spring 2014, the design requirements were significantly more extensive than in 2013 (60-acre v 10-acre site) so it is not surprising that less emphasis was placed on sustainability. Additionally, as the sub-discipline of sustainability matures, the expectations of professionals is likely to increase, which is what we believe occurred from 2013 to 2014. The trend toward improved performance in the problem statement, overall presentation and professionalism is likely due to an increased emphasis (with tutorial sessions) on the use of PowerPoint in oral presentations, and greater expectations for the use of AutoCAD and Google Sketch-up in the presentations. In both 2013 and 2014, student teams were required to practice their presentations before CE 495 alumni. These practice sessions gave students the opportunity to present and obtain feedback.

A multifactorial analysis of variance (ANOVA) was conducted to investigate the significant statistical differences among different teams and years for all rating categories. Table 1 shows the partial results of ANOVA for each rating category. It should be noted that if the interaction between two factors is significant, the conclusions should be based on the interaction effects and not the main effect of individual factors. For example, the results in Table 1 show that there is a

Table 1. Analysis of variance results for professional ratings

Effect	Variable	SSE	df	MS	F	Sig.
Team	Problem stat.	7.33	6	1.22	3.60	.00
	Sustainability	9.04	6	1.51	2.74	.02
	Presentation	8.58	6	1.43	3.54	.00
Year	Problem stat.	2.08	1	2.08	6.13	.02
Team × Year	Presentation	8.68	5	1.74	4.30	.00

significant interaction among different teams between years for the presentation category, i.e., the presentation ratings are significantly different among teams in different years. Although the main effect of team is statistically significant for the categories of problem statement, sustainability and presentation, only interaction effects between team and year are important for presentation category. The results show that there are significant differences in the mean professional rating among teams and between years for the problem statement category while the ratings for sustainability are only statistically different among teams for sustainability category. Fig. 2 shows an example of mean professional ratings for the

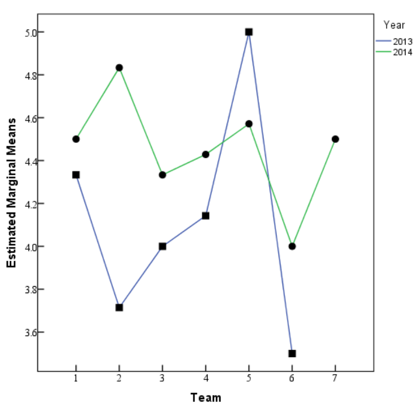


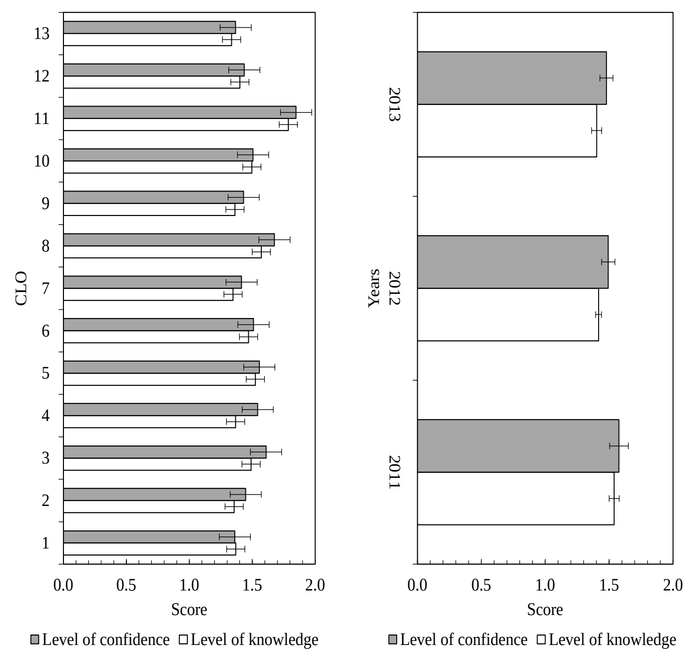
Fig. 2 Variations of rating for among teams for different years (problem statement)

problem statement category between different years. The results show that significant variations exist in the mean rating among different teams for different years although students were assigned to different groups based on their expertise, interests, and a lottery system meant to equalize the teams. The data shown in Fig. 2 indicates that despite attempts to equalize the teams, the performance of the teams varies significantly. This is consistent with observations by the lead faculty members.

B. *Student assessment of their mastery of CLOs*

Student mastery of CLOs is measured indirectly by asking the students a series of questions in which they rate their own mastery of the material. The survey, which is completed in the last week of the semester, asks students to (1) "grade" your level of knowledge of this objective at the END of the course and (2) "grade" how confident you would feel explaining what you learned about this objective to another student. The grading is done on a 5.0 scale with an A being a 1.0 and an E being a 5.0. Thus, the lower, the score, the better the students believe that they have mastered the material in the course.

Fig. 3 presents the variations student self-assessments for mastering CLOs and learning among three different years (multiple semesters). It can be observed that generally, level of confidences is rated high by students while their level of confidence is consistently lower for all CLOs and among different years.



(a) CLO mastery (b) Mastery with years

Fig. 3 Student self-assessments for CLOs by year

The ANOVA results for level of knowledge gained by students for different CLOs and years show a significant interaction between CLOs and years, which depict that level of confidence for learning, vary among CLOs in different years. Fig. 4 presents the variations of scores among different CLOs by year. The results show a significant improvement in student level of confidence in year 2013, especially for CLOs 3, 8 and 11. These variations among years can be attributed to different teaching styles of faculty in different semesters. In 2013, much greater emphasis was placed on sustainability, with the addition of several lectures on sustainability in civil engineering, LEED certification, and low impact development. In addition, the lead faculty worked extensively with students to help them learn how to write technical and non-technical reports.

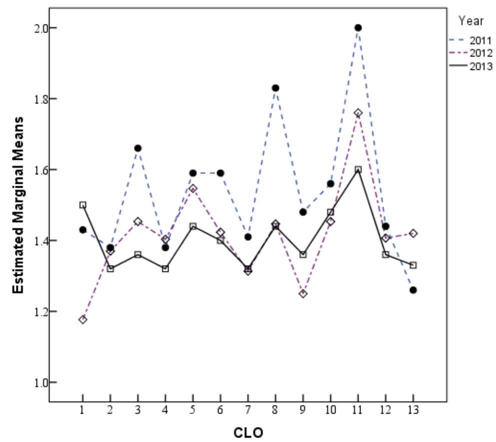
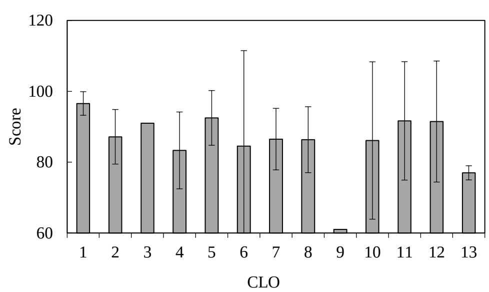


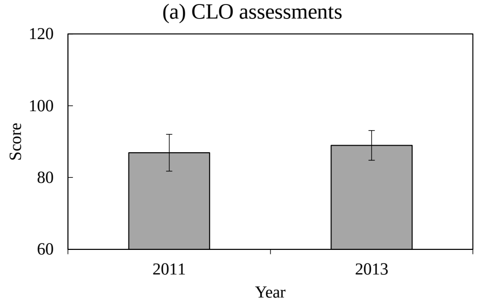
Fig. 4 Variations of student self-assessments for different years (level of knowledge)

C. CLO assessment for ABET

As a part of the ABET accreditation, faculty members assess the student mastery of CLOs at the end of a semester. These assessments are based on the grades obtained by students for different deliverables (quizzes, home works, exams or project reports and presentations) related to a particular course learning objective (CLO). The data from two different years were analyzed to investigate the CLO assessment. Fig. 5 presents the variations of the scores achieved among different CLOs and years.



(a) CLO assessments



(b) Assessment by years

Fig. 5 Variations of CLOs Assessment

(>75%=outcome achieved and <75%= fail to achieve)

It should be noted that if 75% or more of the students in class achieve greater than 75 out of 100 points in a particular course deliverable, the outcome for that CLOs will be considered as achieved for ABET accreditation. The results in Fig 5 show that for CLOs 9 and 13, the CLOs were not achieved. It is not surprising that students struggle with coordinating their efforts across the specialty areas, especially given that one of the major challenges in the course delivery is the coordination of the sub-disciplines and the collaboration amongst faculty. Surprisingly, despite the emphasis on individual effort and self-learning, students do not seem to relate these efforts to life-long learning. A significant interaction effects between CLO and year was observed suggesting a significant mean differences exist between CLO assessments in different years. Such variations again can be attributed to diverse teaching styles of faculty members in different semesters.

V. CHALLENGES

As was reported by Stanford et al. [6], technology has played an increasing role in our capstone design courses. However, the emphasis of the consulting faculty on the use of technology varies greatly. In addition, the use of a common grading rubric has been met with significant resistance. Another challenge has been ensuring consistency amongst the various scopes for the different disciplines. It is not uncommon for students to perceive one subdiscipline as easier than the others, and therefore, these results in a disproportionate number of students requesting that discipline. There is little consistency in the feedback given by the consulting faculty. A final challenge has been ensuring that each of the sub-disciplinary scopes fit into the overall design project. An example of such a problem occurred when the structures project for a “Design Building” did not truly fit into the PUD but seemed like a forced match. This presents challenges to the students in developing and presenting their design. However, the experience is viewed positively by both the students and the participating professionals as preparing students well for the “real world”.

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University Wide Program Management for Quality Assurance of Undergraduate Research

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***Abstract*— Undergraduate research is an opportunity for students to perform actively research under supervision of faculty. Students develop problem-solving, engineering design, and project management ability. Since undergraduate research is individually executed by each student in guidance of diverse fields of faculty, quality assurance is the most important to obtain educational outcomes. We have been managing a whole university program for quality assurance of undergraduate research. A Working Group for Quality Assurance has been organized to plan and implement the program which includes performing Quality Assurance of undergraduate research. The working group consists of 17 faculty members who represent each department, 10 staffs from divisions. Each department carries out a project in the department for quality assurance. The university wide program management has planned and provided a policy and guidelines for quality assurance. The World Cafés were held to share the designs and experience of departments. Program management as an integration of department level projects is indispensable and effective for project management in universities, because synergy effect by variety of career, disciplines, and experiences of faculty and staff contribute the success of program.**

Keywords*— *Program Management, Educational Innovation, Undergraduate Research, Quality Assurance, World Café;

I. INTRODUCTION

Undergraduate researches have been carried out as courses for students in engineering and science universities. In some countries, the undergraduate research is a privilege only for students whose research proposals were adopted [1] [2]. Most Japanese universities in engineering and science have delivered undergraduate researches for senior students [3]. Undergraduate research is an opportunity for students to perform actively research under supervision of faculty. Students develop problem-solving, engineering design, and project management ability. Since undergraduate research is individually executed by each student in guidance of diverse fields of faculty, quality assurance is the most important to obtain educational outcomes.

II. ENGINEERING EDUCATON WITH PROJECT BASED LEARNING AND RESEARCH

Shibaura Institute of Technology is a university with 17 departments in 3 colleges and nine divisions in two graduate schools. The Institute has been making effort to improve engineering education and introduce active learning. We have introduced series of PBLs and undergraduate research to engineering education. Figure 1 shows evolutional project-based learning courses of systems engineering and project management [4] [5] which are held by College of Systems Engineering Science and consist of seven PBL and four lectures on systems engineering. In the curriculum, PBLs and lectures are executed alternately and evolutionally. Undergraduate students take undergraduate research after they have executed series PBLs for engineering design education.

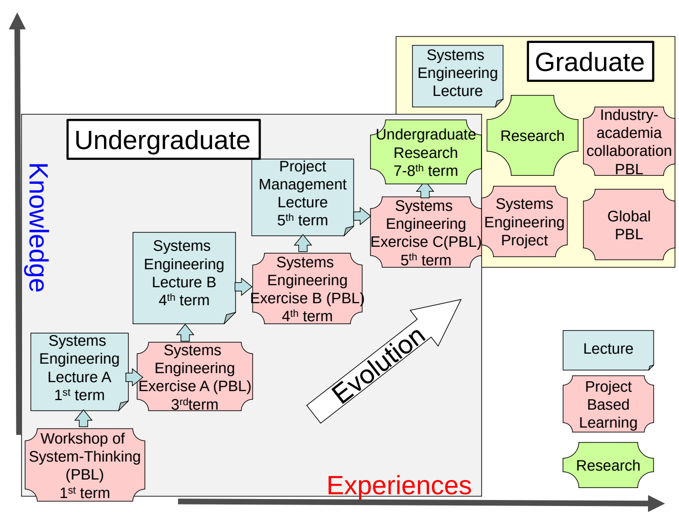


Fig. 1. Engineering Education with PBL and Research

III. PROGRAM MANAGEMENT FOR EDUCATIONAL INNOVATION

Since FY2011, we have been executing a university wide program for quality assurance of PBL and undergraduate research. Because all faculty members are engaged in undergraduate research, we have selected quality assurance of undergraduate research as university wide program.

First purpose of the program is to define clearly role of the undergraduate research in educational objective for each department. The second purpose is to establish means to assess student performance for continuous improving of the research. Third purpose is to share the knowledge and experience of faculty members and staffs to carry out quality assurance of undergraduate research.

Table I. Overview of Project, Program, and Portfolio Management [7]

Organizational Project Management			
	Projects	**Programs**	**Portfolios**
Scope	Project have defined objectives. Scope is progressively elaborated throughout the project life cycle	Programs have a larger scope and provide more significant benefits.	Portfolios have an organizational scope that changes with the strategic objectives of the organization.
Change	Project managers expect change and implement processes to keep change managed and controlled.	Program managers expect change from both inside and outside the program and are prepared to manage it.	Portfolio managers continuously monitor changes in the border internal and external environment.
Planning	Project managers progressively elaborate high-level information into detailed plans throughout the project life cycle.	Program managers develop the overall program plan and create high-level plans to guide details planning at the component level.	Portfolio managers create and maintain necessary processes and communication relative to the aggregate portfolio.
Management	Project managers manage the project team to meet the project objectives.	Program managers manage the program staff and the project managers; they provide vision and overall leadership.	Portfolio managers may manage or coordinate portfolio management staff, or program and project staff that may reporting responsibilities into the aggregate portfolio.
Success	Success is measured by products and project quality, timeless, budget compliance, and degree of customer satisfaction.	Success is measured by degree to which the program satisfies the needs and benefits for which it was undertaken.	Success is measured in terms of the aggregate investment performance and benefit realization of the portfolio.
Monitoring	Project managers monitor and control the work of producing the products, service, or results that the project was undertaken to produce.	Program managers monitor and the progress of program components to ensure the overall goals, schedules, budget, and benefits of the program will be met.	Portfolio managers monitor strategic changes and aggregate resource allocation, performance results, and risk of the portfolio.

A. *Program Management*

We have introduced program management (Table I) [6] [7] for quality assurance of undergraduate research. The Project Management Institute (PMI) defines program as "A group of related projects, subprograms, and program activities that are managed in a coordinated way to obtain benefits not available from managing them individually." Program management is the application of knowledge, skill, tool, and technique to a program to meet the program requirements and to obtain benefits and control not available by managing project individually [7].

B. *Program and Project Organization*

University initiated an educational innovation program which has steering committee consisting of president, vice president, deans, and general managers of administration. A Working Group for Quality Assurance has been organized to plan and implement the program which performs Quality Assurance of undergraduate research. The working group consists of 17 faculty members who represent each department, 10 staffs from most divisions, and a program manager who is a deputy president in charge of quality assurance of education.

Two story program management has been organized with department level projects and a university-wide program for integrating and managing all the projects. Each department carries out a project in the department for quality assurance. The university wide program manager developed a program plan and provided a policy and guidelines for quality assurance project.

C. *PDCA cycle of Quality Assurance*

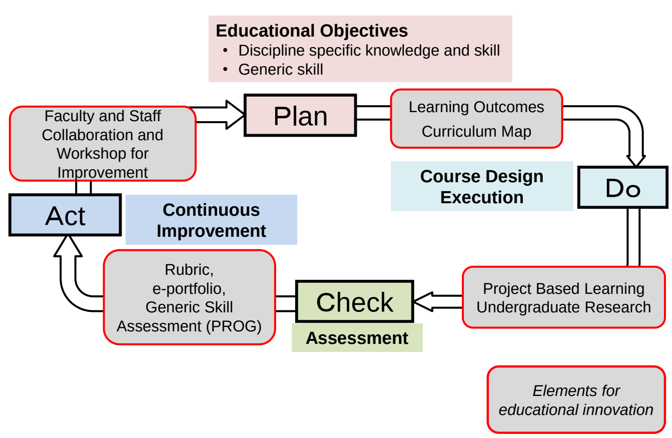


Fig. 2. Plan, Do, Check, and Act (PDCA) cycle of Quality Assurance

Plan, Do, Check, and Act cycle in quality assurance for educational innovation are shown in figure 2. In planning phase, we determined educational objectives for discipline specific knowledge as well as generic skills. After executing project based learning and undergraduate research, we assessed learning outcomes by rubric, learning portfolio, and generic skill assessment test (Progress Report on Generic

Skills, PROG) [8]. Utilizing result of assessment and experience of faculty members of all departments and staffs, we had faculty – staff collaboration workshop to improve quality of education.

D. World Café for University Wide Program Management

A café is a type of restaurant which usually serves coffee and snacks. It is known as a place where information can be exchanged to create new values and relations. The World Café [9] is a structured conversational process in which groups of people discuss a topic at several tables, with individuals switching tables periodically and getting introduced to the previous discussion at their new table by a "table host". Individuals write on the tablecloth so that when people change to different tables. They can see what previous members have expressed.

University wide workshops in World Café style have been executed five times in last three years. The World Cafe is the core of program management tool to share the program objective, knowledge, and experience of the whole university for quality assurance. President, vice president, twenty faculty members from departments, ten staff from most divisions, and five graduate students have participated in most workshops. The workshops are faculty-staff-student collaboration opportunity to innovate education.

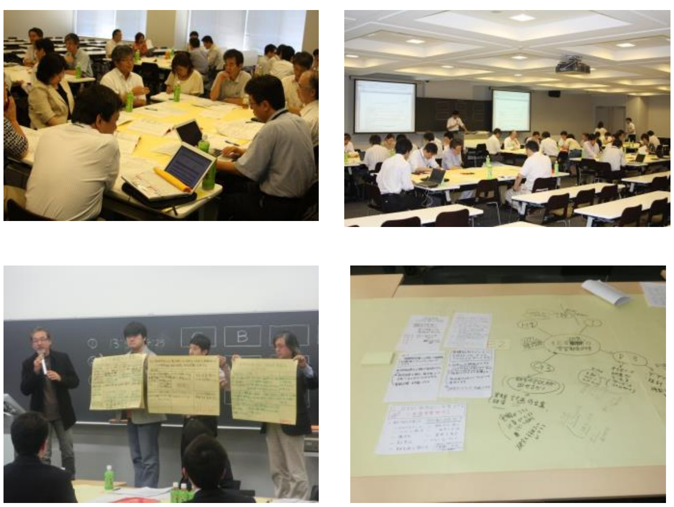


Fig. 3. World Café of Faculty, Staff, Student Collaboration for Educational Innovation

University wide workshops with World Café have been held on Saturday afternoon. Faculty members from 17 departments in three colleges sit on five or six initial tables. About ten Staffs and five students are distributed to the tables. Faculty and staff have different view to students; faculty in each department teaches and observes the students in the department closely, whereas staffs observe many students in plural departments. Faculty-staff-student collaboration workshop is effective to share knowledge, experience, and point of view to innovate education. Our typical work shop has one hour presentation from program manager, faculty, staff, and student, and two hour World Café to exchanging ideas and experiences.

Procedure of our World Café in work shop:

1. Opening: Café host introduces objective and procedure of World Café.

2. First round conversation

Individuals in each table exchange idea and exprience, and discuss on the topic. They record their conversation on the tablecloth. They are required to decide a table host who stay at the same table during the World Café.

3. Second round conversation

Table host stays at the same table. The others move to the other tables. Table host introduces the conversation on the table. Individual also introduces the conversation at previous table. They also exchange idea and experiences and write down on the tablecloth.

4. Third round conversation

Individuals return to original tables. They introduce the conversation at second round table and continue conversation.

5. Wrap-up

Table host and individual on original table wrap up result of conversation to share idea and experiences.

6. Plenary session

Each table host introduces the result of each table.

E. University Wide Program of Qualigy Assurance

In 2011, all departments decided educational objectives and some departments designed rubrics [10] [11] for undergraduate research. A rubric is a scoring guide that clearly differentiates levels of student performance. The World Cafés were held to share the designs of rubrics and experiences of departments in July, September, and November, 2011.

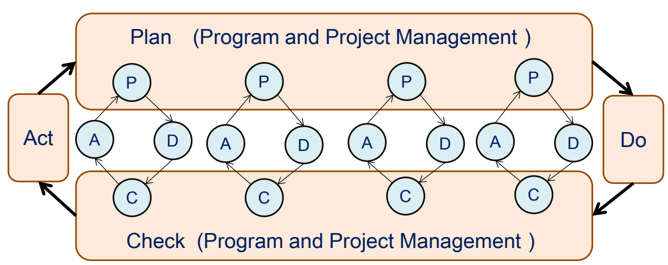
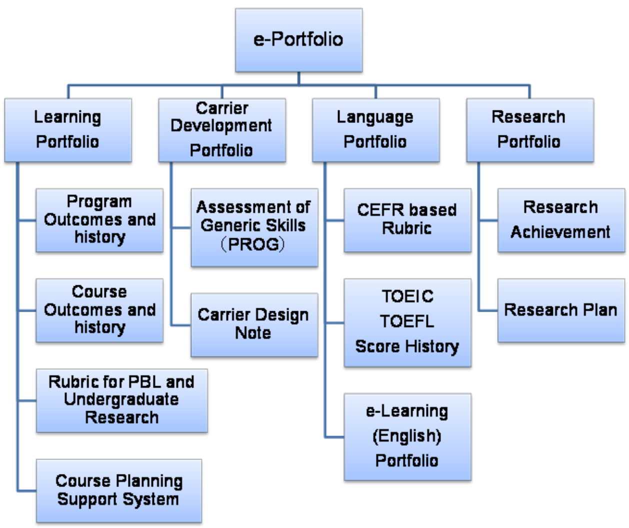


Fig. 4. University Wide Program Management for Quality Assurance of Undergraduate Research

In 2012, each department shows the educational objectives and the rubrics to students. In the middle of undergraduate research, intermediate evaluation with an oral presentation and a poster presentation were held with students' reflection on their performances by using rubrics. The experiences of all departments were shared in World Cafe held in October.

In 2013, the rubrics were revised based on university-wide experiences and applied to undergraduate researches. An electronic learning portfolios based on the rubrics were introduced to give students opportunities of performance reflection. In Word Cafe held in November, best practices and experiences on rubrics and electronic learning portfolio were shared by all departments.

Till the end of FY2013, most departments have successfully established the educational objectives and rubrics, and utilized rubrics for assessing and/or reflecting purpose of students' performance. Moreover several departments applied electric portfolio for students to reflect their performance.



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

Fig. 5. E-Portfolio with Rubric for Undergraduate Research

E-Portfolio consists of learning portfolio, carrier development portfolio, and language portfolio, and research portfolio. Learning portfolio has outcomes and rubrics for undergraduate research.

IV. CONCUSION

University wide program for quality assurance of undergraduate research has been executed. Program management for integrating department level projects is important in universities, because synergy effect by variety of career, disciplines, and experience of faculty members and staffs contribute the success of the program and each project. World café style workshop with faculty, staffs, and students are an effective program management tool for university to make educational innovations.

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Additive Manufacturing in First Year Engineering Undergraduate Experiential Design

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***Abstract*—The importance of engaging the student in a first year design course cannot be understated. In recent times the pendulum has swung in favour of a more theoretical curriculum for the engineering student, causing what many would argue as a loss of the practical engineer. Certainly first year engineering design curriculum is guilty of following this path. Through the introduction of inexpensive three-dimensional printers, a normally abstract solid modelling course steps into the domain of systems design and practical considerations in manufacturing process. The author will present an overview of implementing three-dimensional printing in a first year design and provide the results of recent research into how this addition to the course has impacted student learning.**

***Keywords*—engineering design, experiential education, project based learning, simulation based learning, additive manufacturing, 3D printing**

I. Introduction

As the instructor of a first year engineering Design & Graphics course, the author has attempted several iterations of the curriculum with review and reflection on what it means to teach design. Coming from the author's own experience with a traditional focus of *form*, the course has been transformed into a system modelling approach that places emphasis on *functionality* of design. Given the increasing global trend to incorporate experiential education at all levels of engineering curriculum [1]–[3], the author implemented a project based approach taking students through a complete design cycle beginning with theory and ending with manufacturing.

To achieve this transformation, the author modified a mechanical dissection project [4] into a reverse engineering retrofit of an existing gear train [5]. To effectively analyze and assess such a project, the course adopted a multi-domain physical modelling software application [6] that permitted first year students an experiential interaction with a three-dimensional simulation of their designs. The real-time interaction gave students the ability to close the design loop through verification of theory and intermediate design steps, with the complete validation of the system function. However, at this point the resultant design was still digitally abstract and for some students difficult to visualize. By incorporating 3D printing, all students could bring the abstract digital into the physical [7]. The physical models were be manufactured using three-dimensional printers available to the first year students in McMaster Engineering-1's Experiential Playground and Innovation Classroom (EPIC) [8].

As this is an introductory engineering design course there is no assumed knowledge prior to entering the course. The student is first exposed to the concepts of solid modelling and just prior to the midpoint of the course, where students have basic solid modelling assembly skills, the course focus become framed around the concept of simple mechanisms. The team design project is introduced and as the course progresses, teams are able to immediately apply the material to their project. The topics and project unfold in the following order (illustrated in Fig. 1) to form a complete design loop:

1) Simple mechanisms,
2) ideal gears and gear pairs (calculations and solid modelling),
3) gearing ratio and standards (solid modelling tools for gear design – Autodesk Inventor's Design Accelerator),
4) simulation of gear pairs (real-time, interactive 3D simulation – Maplesoft's MapleSim),
5) multistage gear train design,
6) validation and verification of design, and
7) manufacturing (3D printing).

The experience in developing and researching this teaching methodology has presented the author with a unique perspective on student engagement, performance, and perception of a systems approach to teaching design. In the author's reflection on teaching design, it became apparent that

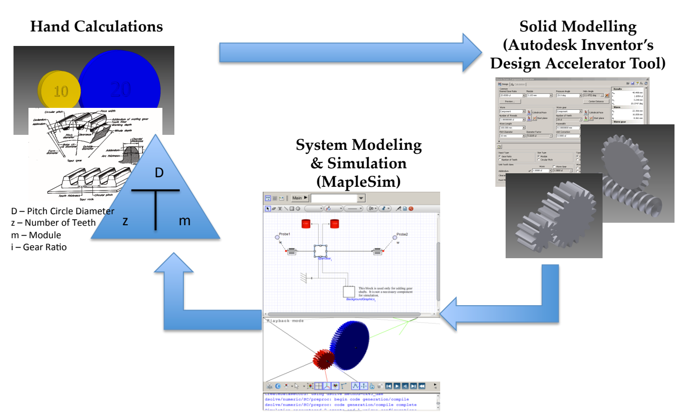


Fig. 1: Design loop.

the traditional approach of focussing on form often was done by demonstrating design, but rarely providing opportunity for the student to meaningfully work through design. The author believes that this transition to function design through experiential learning and project-based learning is the ideal teaching approach and methodology for introductory engineering design.

II. Background

Over the past few decades the trend in first year engineering graphics courses has gradually transitioned from drafting tools to computer aided design while the scope of many are expanding to teach design. These changes have many educators reflecting upon the teaching of design; especially for courses that are now placing significant emphasis on the engineering educational experience.

The first year Design and Graphics course at McMaster University is part of a common year. The course runs in the Fall and Winter terms with approximately 450 students each term and is structured with lecture, lab, and tutorial each week. Since 2006 the course has evolved from the more traditional focus on CAD and hand sketching, to incorporate dissection, mechanism design, system modelling, and rapid prototyping.

A. Form vs. Function

While most students become adept at using the CAD software, the traditional assessment focus on the *form* of a design results in many students that have little functional understanding of the parts and assemblies they are modelling. This result highlights the problem with many traditional graphics courses because the emphasis of assessment is based on the mechanical form and not on the function.

In part, this is the result of increased class sizes, limited resources, and insufficient tools. The incorporation of a system modelling tool for visualization and simulation into traditional design and graphics courses permits students to gain insight into the mechanical *function* of the mechanisms they are creating. A system modelling software application would also facilitate the evaluation of the function of a mechanical assembly.

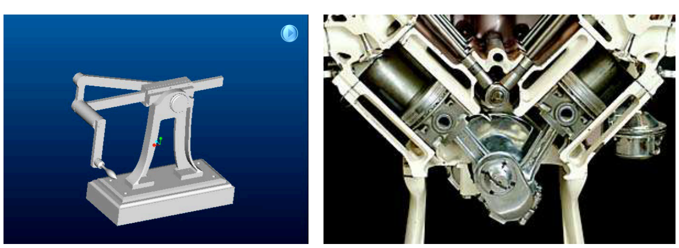


Fig. 2: Simple mechanism and application: a) the slider-crank , b) piston motion.

B. Mechanisms

To reframe the course context, students are introduced to simple mechanisms and shown how such assemblies are found in all technology domains. first year students are intrigued to learn that a simple slider-crank mechanism [9] concept is easily observed in the firing of a piston and crankshaft motion in the common internal-combustion-engine [10], as shown in Fig. 2. Providing the tools to harness and drive this intellectual curiosity gives students the ability to experiment with different designs.

The mechanisms introduced are the combinations of spur gears, worm, worm gears, and rack gears. The discussion quickly transitions from intuition into the theory of simple mechanisms for the translation of motion. Once the basics of hand calculations and design parameters (e.g., gear ratio, diametral pitch, etc.) are introduced, the student can create the CAD solid model. Fig. 1 illustrates the iterative process the student follows in designing the functional mechanism.

C. Systems Approach & Modelling

The system modelling merges the design form and function into a real-time interactive tool which permits the student the ability to close the design loop through iterative verification. This approach permits experimentation by the student and confidence in connecting their course knowledge to a practical application.

The complexity of a system modelling and simulation software application is non-trivial and its inclusion in a first year design course was not without serious consideration. The objective was not to add another tool that would distract from the course objective of teaching functional design. To remain focussed on the solving the problem, and not become distracted by the tool, students are given generic gear-pair modules (spur-spur, worm-worm gear, worm-rack) that are to be customized with hand calculation and solid model geometries. Fig. 3 shows a generic spur-spur gear pair module and the generated simulation. By providing these modules, the instructor provides the scaffolding necessary to focus on solving the design problem, rather than starting at ground level of the software application. Solving the design problem requires the cascading of the provided modules to create a much more complex gear train with specific space and time constraints.

Once the student completes their iterative verification of functioning stages of their designs, the finalized design and full validation can be conducted. Fig. 4-a), b), and c) present a student submission of CAD assembly model, system model simulation, and an example virtual probe measurement of linear displacement *vs.* time. With this feedback students can then proceed to the rapid prototyping of their physical model.

D. Rapid Prototyping

The final stage of the course design project is the fabrication of the model using a rapid prototyping three-dimensional printer. This brings the abstract model out of the digital simulation and into the hands of the student. The advent of low cost rapid prototyping printers [11] allow for students to directly intact with the machines. Fig. 4-d) is a photo of the final physical model after the solid and system modelling.

III. Pedagogical Research

There are two aspects of this approach to design education we have been able to study: perception, and performance.

A. Perception

Our perception study [12] focussed upon the impact this type of experiential learning would have on the perceived self-image of the student and how that effects learning. This research found that students experienced increased self-efficacy and sense of belonging to the Engineering profession. This was most notable in Mastery experiences and Involvement, where responses were higher for the Post-Project Group. Students felt more confident in their perceived engineering capabilities and felt a greater sense of community and involvement.

B. Performance

Our performance study [13] found this teaching approach had a positive impact on visualization performance for many students. The system simulation software was an effective method of implementing project based learning and design education in engineering, particularly in large first year engineering courses.

IV. Conclusion

The availability of low-cost 3D printers makes incorporating the manufacturing phase into a design course possible at any level of engineering. By giving first year students access to such tools and the ability to experience a complete design process is invaluable to engaging the student, giving the student a sense of purpose, and building a sense of community. Such factors can be less evident to first year students when courses are abstract or pure theory. Furthermore, the manufacturing phase not only allows student to physically hold their original concepts, but also demonstrates some of the challenges faced in manufacturing that are beyond what the textbook offers.

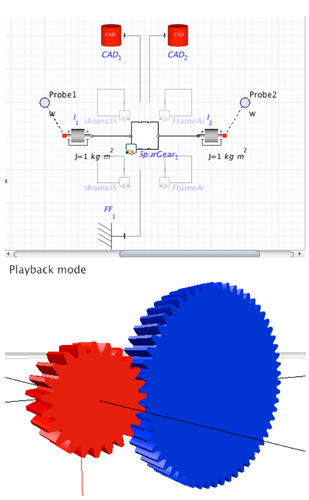
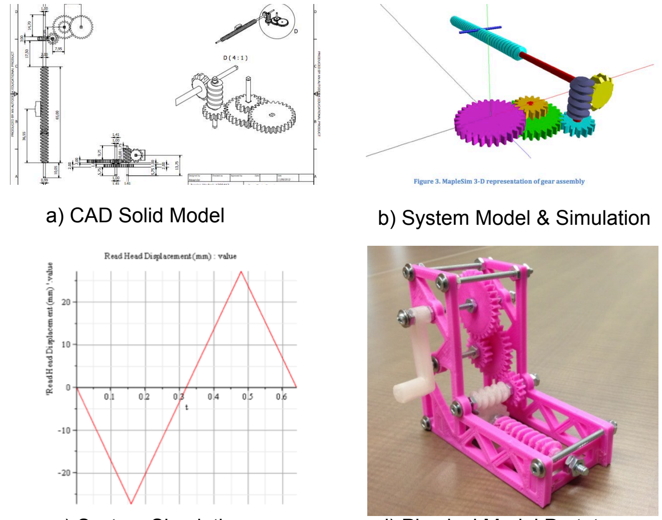


Fig. 3: Single spur gear pair module: scaffolding the system modelling to focus on the design, rather than the tool.



a) CAD Solid Model

b) System Model & Simulation

c) System Simulation Validation

d) Physical Model Prototype

Fig. 4: Example student design and prototype.

The author's presented approach to teaching introductory engineering design is transferrable, scalable, and could be readily adopted by courses or programs that would benefit from both either simulation-based, or project-based learning. In addition, the measure of competency based outcomes (i.e., accreditation requirements) is well suited to this modality.

Acknowledgment

The author would like to thank his colleague Dr. David Musson, and his research students: J. J. Booth, T. Schwering, and O. Boursalie.

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Very Low Cost Thermofluid Experiments via Vacuum Formed Plastic Hardware for Active Learning in the Classroom

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***Abstract*— The purpose of this research is to develop simple, flexible and very inexpensive experiments that engineering students can manipulate to master concepts in thermodynamics, fluid mechanics and heat transfer while in the classroom. Toward this end, a novel approach to quickly and cheaply design and manufacture experimental hardware has been developed. A four step approach is presented. First, commercial CAD software is used to define the geometry of an experiment. Second, a rapid prototyping machine is used to 3-D print a plastic mold of the design. Third, a vacuum former is used to form thin plastic sheets around the 3-printed mold. Finally, the vacuum formed sheets are assembled together to produce multiple copies of the experiment. The result is an approach that allows the development of experiments that are robust and inexpensive enough to distribute individual copies to each student in a class. This approach opens up the possibility of a wide variety of active learning strategies that can be implemented in classrooms, for home use, and for distance education.**

Keywords*— Active Learning, Classroom Experiments, Inexpensive Hardware;

I. INTRODUCTION

Unfortunately, much student learning in revolves around solving textbook problems. Solving problems helps students develop procedural knowledge but does not necessarily help them develop conceptual understanding. The present work aims to overcome this deficiency by presenting students with inexpensive devices exemplifying important engineering concepts, which the students can readily manipulate in the classroom, to stimulate active learning.

Active learning, especially experiential learning, has been shown by educational researchers to result in superior learning outcomes than traditional delivery methods like lecturing.[1] As a result, educational researchers have developed various active learning activities based on experiments that students can manipulate and learn firsthand for themselves. Several approaches have been taken, with some researchers focusing on take-home experiments that students can undertake as homework, others developing experiments that can be accessed remotely for distance education, and a third group designing experiments for in-class use.

In an example of this first group, T. Scott reported on two fluid mechanics experiments designed to be completed as homework assignments by students in a fluid mechanics course.[2] Students were asked to assemble and use two simple experimental devices. First, the students used a hydrometer to measure and report the specific gravity of common household fluids. Second the students assembled a water manometer from vinyl tubing and used it to measure the differential pressure across the side window of a moving car. In each case the cost of the experimental apparatus was minimal, while the experience of doing the experiments appeared to enhance the students' understanding of the basic concepts involved. Cimbala et al. took a similar approach and developed a take-home experiment in which students characterized the performance of a small aquarium pump, and compared their results with the manufacturer's pump curve.[3] The entire experimental apparatus cost less than $20 for each student, but resulted in a significant gain in learning.

A number of education researchers have developed experiments that can be accessed remotely, so that students can manipulate engineering hardware via the internet. Ogot et al. reported on a jet thrust laboratory that students can access on-line, and perform remotely. In this case, the experimental apparatus was assembled from high quality components and housed and maintained in a traditional laboratory setting.[4] Cost savings came not from reducing the cost of hardware, but from making expensive hardware more freely available. In addition, interaction with the experiment came not from hands-on manipulation of hardware, but via the software interface, Lab-View, and video flow visualization. However, a comparison of students performing the lab hands-on and students performing it remotely indicated statistically similar learning outcomes. Richards et al. documented a similar remotely accessed experiment that allowed student to operate and make measurements on a Venturi nozzle.[5] In this case, an existing lab was retrofitted with internet accessible controls and data acquisition to enable students at branch campuses to remotely perform the experiment. Once again, an assessment of student learning comparing students in the lab and students using remote access indicated similar outcomes.

Finally, significant effort has been devoted to developing experiments suitable for in-class use. In this approach, the goal has been to use student-centered, hands-on experiments during regular class time to replace or supplement lectures or instructor-centered pedagogies. Van Wie et al. have done extensive work in this area, developing a system of compact experiments called Desktop Learning Modules (DLM's) that can be brought into the classroom. The DLM system is based on a series of cartridges that can plug into a base unit with liquid reservoir, pump, and data acquisition. Each cartridge holds the hardware for a particular thermofluid experiment. Cartridges available include heat exchanger, pipe flow, fluidized bed, and venturi nozzle experiments among others. Assessment of student learning using the DLM system has shown significant gains for students using the active learning approach.[6]

Active learning using thermofluid experiments has repeatedly been shown to enhance student learning, whether used outside of class for take-home assignments, for students in remote locations in distance learning environments, or brought into the classroom to supplement or replace lecture-based pedagogies. In all of these applications, a major consideration is the cost of the hardware used. For active learning strategies to be successful, there must be enough experimental stations for each student to manipulate the hardware to be actively engaged. The present work is focused on this specific challenge, developing an approach to design and fabricate experimental hardware that is inexpensive, simple and robust enough to allow each student to have his or her own experimental setup. We expect that by focusing on developing means to manufacture very low-cost devices, those devices will form the basis for active learning experiences that will meet a broad range of engineering curricular needs.

II. APPROACH

The approach developed here is based on design for manufacture, leveraging new manufacturing modalities such as rapid prototyping through 3-D printing and vacuum forming to produce an array of simple, inexpensive, easy to use experimental hardware. We believe that end product cost reductions can be achieved, by designing the hardware to take advantage of specific strengths of new manufacturing routes, use of inexpensive materials, and simplicity of concept.

A. Leveraging New Manufacturing Techniques

Recently developed manufacturing techniques are opening up new ways to fabricate devices that can help students learn engineering concepts in ways that are more motivating and that lead to deeper understanding. Leveraging these new manufacturing approaches can enable educators to design and fabricate experimental hardware for student use in ways that are dramatically less expensive and more flexible than anything heretofore seen. These new manufacturing techniques are expected to result in products so inexpensive to produce, that every student in a course will be able to have their own device to manipulate and explore.

The key to this approach is to make design for manufacture a primary consideration, from the beginning of the development cycle for each experiment. Thus, each device must be considered from the perspective of reducing the number of parts to the absolute minimum, designing those parts for easy assembly, and fabricating the parts using simple, fast, and flexible processes requiring little or no skilled labor, while using very low cost, readily sourced materials. To achieve these goals we propose to rely heavily on three current manufacturing processes: Computer Aided Design or CAD, 3-D printing and vacuum forming. CAD is used first, for quick and precise definition of complex geometries of experimental hardware and second to quickly explore multiple design geometries. Likewise, rapid prototyping or 3-D printing will be used in two ways. First, 3-D printing will be employed to prototype experiments to rapidly explore variations of geometry on device function and ease of use. Second, it will be used to produce molds for vacuum-formed parts. Vacuum-forming will be employed to mass produce parts for devices, based on the 3-D printed molds, from thin plastic sheets. This approach, starting from CAD defined geometries, to 3-D printed molds, through vacuum forming, to produce parts that can be assembled into complete devices, is expected to lead to very low cost devices and very fast design, fabricate and test iteration. Figure 1 outlines this design and fabrication strategy.

One particularly appealing advantage of the proposed fabrication route is that it can take advantage of the tight integration between widely used CAD software and 3-D printers. That is, it enables hardware design via CAD, simplifying the specification of the precise geometries necessary for the working engineering devices desired. It means that numerical analysis software (CFD or finite element structural software) can be integrated into the design of experiments to predict and optimize device behavior. It allows multiple designers to explore alternate design paths simultaneously, and significantly speed up the design turn-around times. The use of CAD software with 3-D printed prototypes means that design iterations are expected to take hours or days instead of weeks or months as for traditionally machined parts. Likewise, costs for prototype designs are expected to be much less than for machined parts, with single iterations of an experiment costing only a few dollars for materials and processing.

A significant advantage of producing educational hardware using 3-D printers driven by CAD software is that many undergraduate mechanical engineering students now learn to use these commercial tools in introductory engineering courses (freshman and sophomore level design classes). As a result we anticipate the possibility of students participating in the design process of later iterations of hardware. Thus, students using the experiments should be able to see and understand exactly how that hardware was designed and manufactured. In addition, it may be possible for students

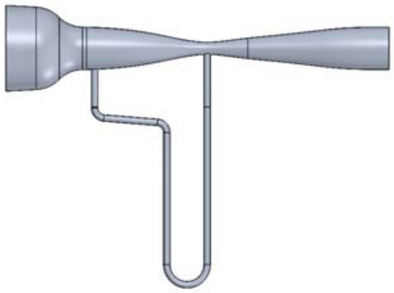

Figure 1. CAD Drawing of Venturi Nozzle

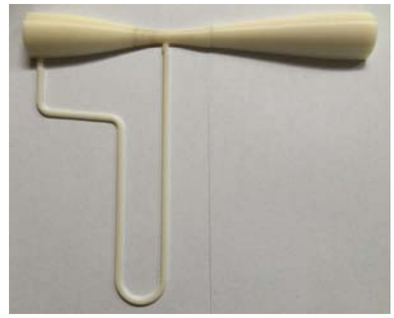

Figure 2. 3-D Printed Mold for Venturi

using the experiments to propose their own modifications of the hardware. Quick turn-around on fabrication via 3-D printing and vacuum forming will make the option of students or instructor driven modification of any given experiment a real possibility.

B. Design of Experiments

In order to explore the design and fabrication of very low cost experimental devices that students can actively manipulate to experience first-hand specific engineering principles, we have begun the development of four experiments: (1) a Venturi nozzle, (2) a pipe flow apparatus, (3) and a concentric pipe heat exchanger. The venturi nozzle experiment will be designed to demonstrate the way energy is transferred between static pressure (or potential energy) and fluid velocity (or kinetic energy), as a fluid passes through a converging nozzle (conservation of mechanical energy). The pipe flow experiment will illustrate how static pressure falls as a fluid moves through a pipe (conservation of energy), while fluid velocity remains constant (conservation of mass). The concentric tube heat exchanger should enable students to explore how fluid-flow rates and flow geometry, affects change in temperatures of two fluids as heat is transferred between them (conservation of energy & heat transfer). For these experiments to be effective, the experimental hardware must enable students (1) to readily control fluid flow rates through the devices and (2) to easily visualize and measure fluid flow rates, pressures and temperatures.

The first requirement, controlling fluid flow rates through the experimental hardware, is one of the most important decisions in the design of these devices. In the commercially available Desktop Learning Modules or DLM's, fluid flow is driven by a pump in the base unit. This use of pumps for water or fans for air, gives maximum flexibility and control over flow rates, but unfortunately also adds cost and complexity to the system.

To avoid this cost and minimize system complexity, Golter et al. has also used hydrostatic head to drive fluid flows in desktop experiments.[7] In this approach, experiments are connected by flexible tubing to fluid reservoirs, whose heights can be raised and lowered to increase or decrease hydrostatic head and resultant flow rate. While the obvious advantages of this approach are simplicity and low cost, the primary disadvantages are the limited range of pressures available to drive fluids, and the limited time students will have run experiments before a supply reservoir runs dry. First, hydrostatic heads of greater than one meter will be impractical with this approach, limiting pressures to less than 10 kPa. This in turn, will limit the range of fluid velocities, and Reynolds numbers available for experiments. Second, reservoir capacity will necessarily be limited to what students can conveniently handle.

The second requirement, the ready visualization and measurement of fluid flow rates, pressures and temperatures also will have a large impact on the success of the devices, so too the choices of techniques to measure flow rate, pressure and temperature are crucial. Measurement techniques must be robust, simple to employ, as intuitive as possible to interpret, with relatively low uncertainty and above all inexpensive. If at all possible, students should be able to easily grasp the physical concepts underlying the measurement techniques. For these reasons, we have chosen to use simple positive displacement methods to measure volumetric flow rates, liquid manometers for pressure measurements, and non-contact infrared thermometers for temperature measurements.

Volumetric flow rates will be determined by measuring the time required for reservoir levels to change by a unit volume. This approach yields the most direct, and the most easily understood measure of volumetric flow rate. Students will be able to observe and quantify flow rates entirely through basic first principles.

Pressure measurements will be made using liquid manometers molded into the fluids experiments. In this way, pressure measurements will mirror the approach used to apply the pressures driving flow through the fluids experiments. In both cases, students will be monitoring pressures by watching the heights of fluid columns. Thus, fluid height will give a visual indicator proportional to pressure. This approach results in the significant pedagogical advantage that the height of a liquid column gives an easily interpreted visual cue as to the pressures in the fluid, with the proportionality between fluid pressure and reservoir height giving students an easily-understood, measure of pressure.

Figure 3. Vacuum formed Venturi Nozzle

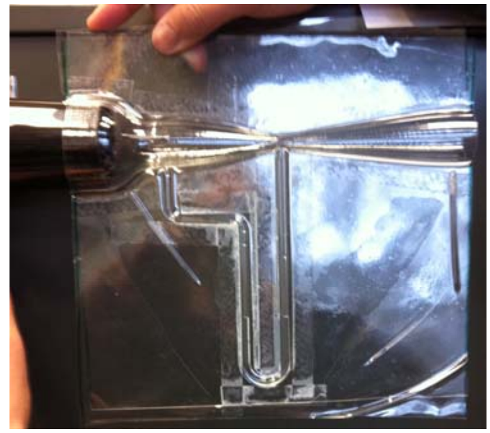

Figure 4. Venturi Nozzle in use.

Temperature measurements will be made using non-contact infrared thermometers. While this choice of techniques is robust, simple to employ, has relatively low uncertainty and is quite inexpensive, it is doubtful that students will find infrared thermometers intuitively easy to understand or to interpret. Unfortunately, we could not identify a commonly available temperature measurement technique whose function was based on physical principles students could easily grasp. The choice of infrared thermometers, while not transparent in operation and function is still an inexpensive and very flexible means of measuring temperature. In particular, since infrared thermometers measure temperature without contact, no sensors or transducers need to be installed on experiments. This fact enables the use of a single instrument to measure temperatures in multiple locations on one experiment, or on multiple experiments.

III. RESULTS

An initial prototype experiment recently manufactured in our labs can be used to illustrate the proposed approach for the fabrication of the very low-cost experiments. The Venturi nozzle design was developed using SolidWorks™ CAD software. The CAD model was exported to a 3-D printer, to produce a mold to vacuum form 0.20” thick sheets of transparent PETG. One nozzle was assembled by gluing two mirror-image halves together. Differential water manometers, fabricated as an integral part of the Venturi nozzles were used to indicate the differential pressure across the nozzles. Air flow through the nozzles was provided by either inexpensive hair dryers or battery powered air pumps. Figures 1 through 4 illustrate the fabrication of a prototype low-cost venturi nozzle experiment. Figure 1 shows an image of the CAD geometry developed for the venturi nozzle experiment. A differential manometer is seen to be integrated between the inlet and the throat of the nozzle. Figure 2 shows a mold for the venturi nozzle printed in ABS plastic on a Stratasys uPrint SE 3-D printer based on the CAD model. Two mirror image molds are used to form the two sides of the venturi nozzle. The mold shown in Fig. 2 along with its mirror image, also produced on the 3-D printer, are used in an EZFORM LV 1827 vacuum forming machine to produce the two halves of the venturi nozzle. The two mirror image half venturis are vacuum formed in a single sheet of transparent PETG, cut out, assembled and glued together to produce the final venturi, seen in Fig. 3.

Fig 4 illustrates these vacuum formed plastic parts be assembled into a complete system. An inexpensive hair dryer is used to blow air through the nozzle. Water is used as the manometer fluid to measure the differential pressure between the venturi nozzle inlet and nozzle.

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An Embedded Systems Curriculum Design Based on the Software-Hardware Co-Design Methodology

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Abstract—**Based on years of experience in SoC architecture research and chip design, the National ASIC Systems Engineering Research Center in Southeast University develops a complete embedded systems curriculum for high grade undergraduate and graduate students in the program of electronics. The curriculum contains six courses which cover the design spectrum from chip architectures, embedded OSs to application developments. Study cases of real chip design processes, tradeoffs between performance and power consumptions, as well as software and hardware adaptive optimizations are also refined from research projects to support these courses. A series of lab platforms based on self-developed SoCs with lower level optimization experiments are used to deepen the students' understanding of software hardware co-design and co-optimization. To further enrich the practical design ability training for the curriculum, a SEU Embedded Systems Design Contest has been organized every year since 2008.**

The curriculum system has been used in southeast university for almost ten years with positive responses either from students or industry companies who hire the graduates. The curriculum and related materials such as text books, lab platforms have been selected by about ten other universities in China as well.

Keywords— Embedded Systems, Curriculum, Software Hardware Co-Design;

I. INTRODUCTION

There are more than 1000 technology universities in China, and there are more than 4.5 million undergraduate students in these technology universities. Therefore, China has built the largest engineering education system for undergraduate students in the world. Now, software engineering and micro-electronic engineering have become the important branches of Chinese engineering education. Consequently, the embedded system courses can be found in many Chinese universities. However, due to the large number of students, there is a big gap between the industrial requirements and engineering educations in Chinese universities. In Chinese universities, the courses are often constructed in three layers: basic knowledge courses, professional knowledge courses, and special knowledge courses. This rigid course architecture is not flexible to connect with the industrial requirements. Apart from this, the practice in the engineering education is not effective and efficient enough.

The embedded systems now have become one of the most important application areas of computers. The software-hardware co-design methodology is the very basic characteristic of the embedded systems design process [1] due to the much more strict requirements of system performance, costs, power consumption, and stresses of time-to-market as well. However, the embedded systems education is lagging behind the rapid improvements in industries. Most traditional embedded system education focuses on the application development which mainly introduces how to use APIs, SDKs and reference designs from SoC chip providers. Consequently, critical optimizations in performance, costs and power that need deeper understanding of chip architectures, software hardware co-optimizations and system level perspectives are, intentionally or unintentionally, ignored.

The reasons behind the educational absences of these key technologies are because of following challenges: a) the breadth of the embedded systems field limits opportunities for system-level content, especially the content of software/hardware co-optimizations in performance and power consumption; b) the academic background of the students makes them hard to cross the gap between electronic and computer science; c) lack of adequate laboratory platforms addressing system-level alternatives [2].

Undoubtedly, it is impossible to compress all the embedded systems knowledge into only one course and that is why more and more educators construct a series of courses or a curriculum to cover as many aspects as possible [3]. While on the other hand, the complexity of latest SoCs and applications built on them make it much more difficult to introduce software hardware co- design and co-optimization which are very critical to the system performance, costs and power consumption. Thus, we take the advantage of experience in SoC research and design in the National ASIC Systems Engineering Research Center, SEU to design the embedded systems curriculum. The idea, philosophy and methodology of software and hardware co-design are the main thread running through all courses. In order to help the students to strengthen their understandings, we also designed our own lab platforms and labs which reused lots of our R&D results.

Section II introduces the courses architecture and main topics in them. Self designed lab platforms, as well as some lab examples and an out course design contest are introduced in section III. Finally, we will give a brief conclusion in section IV.

II. COURSES DESIGN

In Southeast University, the engineering courses are designed according to the core point "solving practical problems". By the way, the practical teaching and collaboration with industrial companies are also emphasized. According to these rules, the embedded systems knowledge is divided into three main levels: SoC design, software/hardware adaption and co-optimization, application and system design. Although this model is too simplified, it is very useful to guide our curriculum structure design. In the other dimension, there are also three levels in our embedded systems courses: one introductory course, four high level courses in each knowledge level and one practicing lab course (figure .1). All these six courses cover the main knowledge levels in the embedded systems design spectrum. We will introduce these courses in the following.

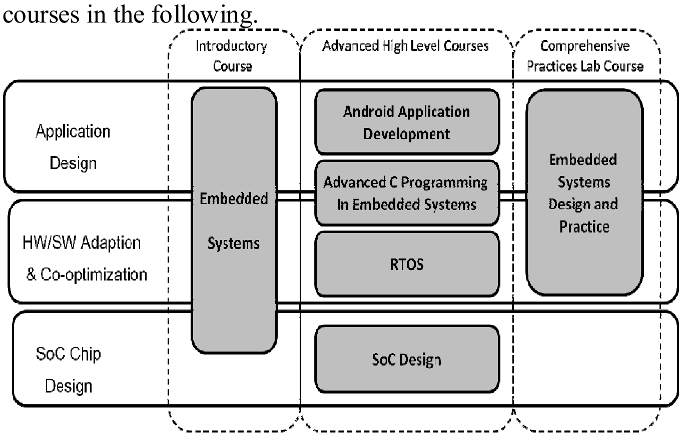


Fig. 1. The courses structure of the curriculum.

A. Embedded Systems

The purpose of the "Embedded System" course is to be the first entry and introductory course for students with electronics background. Different from most other counterpart courses focusing on how to use an off the shelf SoC chip and related tools, libraries and reference designs offered by the chip vendor to build systems, this course stands on the perspective of SoC designers and system architectures to introduce basic concepts and design issues of embedded systems. Because it is an introductory course, a wide range of topics cover most design spectrum should be introduced. The course also help students without any related experience get a global view of embedded systems at the same time. The followings are main contents of the course:

1) SoC architecture and on chip interconnection (including introduction of AMBA architecture and DMA)
2) CPU cores (including Instruction Set and assemble language) and other computing engines
3) Embedded systems developing flow and tools (ICE and on chip ICE, simulators, cross compiling and tool chains)
4) Memory subsystem (including Cache, SPM, DRAM and DRAM controller, nonvolatile memory and virtual memory)
5) Peripherals and IOs (GPIO, Timer, UART, USB, IIC, SPI, IIS, LCDC)
6) Introduction of embedded operating system (Interrupts management, tasks management, inter task communications, priority based scheduler)
7) System low power design (DFS, DVFS, power gating and clock gating)

B. SoC Design

Soc chips are the hardware kernels of embedded systems. More and more function modules, especially high performance computing engines and large size of on chip memories such as GPUs, VPUs, communication basebands, multi-level caches and on-chip buffers and high speed IO interfaces, have been integrated into on silicon die due to the improvements of manufacture technology and the driven force of product requirements. This highly heterogeneous integration makes a very big challenge for SoC designers as well as programmers who will use this chip to build an application. It is very necessary for the system optimization that SoC designers need to know how does the chip's hardware be used by the software and programmers need to know how does exactly the hardware works.

Topics in this "SoC Design" course include: SoC design methodology, SoC architecture, on chip interconnections, on chip memory subsystem, low power design technology, an AMBA master and slave modules design case study and SEP4020/SEP6200 SoCs design case studies.

C. Embedded Operating System

The course of operating system is one of the core courses in almost every computer science curriculum. This maybe not true in an electronics department due to the traditional boundary between two disciplines. Three main targets of our "Embedded OS" course include: 1) to introduce basic concepts and principles of operating system to students in electronics background; 2) let the students understand how does a real time OS works and how to write a concurrent application to control a real time system; 3) help students learn one of the most popular embedded OSs: Linux.

We divide this course into two parts. The first half focuses on the basic concepts and principles of operating system by source code reading and analysis of uCOS/II. OS porting as well as system adjustment and optimization for specified architectures are also covered in this part. Comparing to mechanisms introduction in the first part, how to port, optimize and how to use embedded Linux are the main topics in the second part. The real Linux BSP development experience of self designed SEP6200 processor has been used as the study cases in the teaching process.

D. Advanced C Programming in Embedded Systems

C language is still the most popular programming language in embedded systems design, especially in the performance sensitive and lower level modules. However, introductory C language courses for the first or second year undergraduate students focus on basic syntax issues of the language rather than much more useful and skillful topics such as memory pitfalls, function pointers, debugging tools and skills, interrupt routines(ISR) and re-entry, coding styles and performance optimization issues. In this “Advanced C programming in embedded systems” course, we fill the gap between traditional C language education and the requirements of real embedded system developments by systematically introduce all these advance topics. Our previous research also reveals the effectiveness of this course [4].

E. Android Application Development

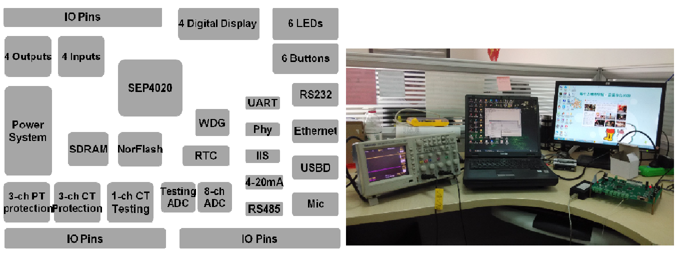
There is no doubt that Android system has become one of most popular and promising application development platforms not only for smart phones but maybe also in other applicants. In this course, we invite senior engineers in companies as lectures who will introduce Android application development in industry perspectives [5]. To help students without Java programming experience, small part of lecture time will be used to cover these contents.

F. Embedded System Design and Practice

Although all the previous courses in this curriculum include in-course labs and assignments, there is no course time for the students to apply and practice all the knowledge they have learned into an almost real system design. The “Embedded system design and practice” course is a project based lab course which encourages students to use what they have learned to accomplish a system design. We use a real motor protector design which is based on the SEP4020 processor as the example to introduce the complete design flow. Topics in this course include:

1) System requirements analysis
2) Hardware system design and schematic design
3) PCB layout and manufacture
4) PCB soldering and hardware system debugging
5) BSP development and OS porting
6) Application development and debugging
7) System testing and optimization

Students are divided into 2-3 people groups and required to complete their own designs after each lecture. A final design report should be submitted and a presentation with the system prototype demonstration by each group will be also held for the mark purpose. The system blocks diagram and the prototype testing environment are shown in figure 2.

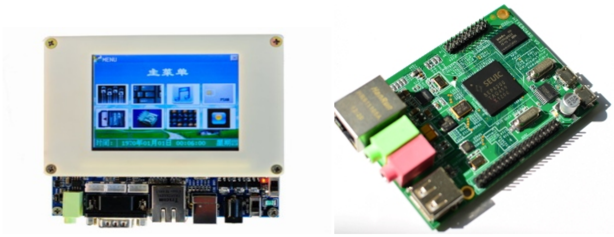


a)System Blocks diagram *b) prototype testing*

Fig. 2. A motor protector design in the practicing course

III. LAB PLATFORMS AND EXPERIMENTS DESIGN

Unlike many other educators choosing third party built or open source hardware as their lab platforms, we design lab platforms using our own designed SoC chips: SEP4020 [6] and SEP6200 [7]. The SEP4020 processor is an ARM720T based general purpose micro controller while the SEP6200 processor is a domestic CPU architecture (UniCore32-2[8]) based high performance application processor with a maximum 800MHz CPU clock and a 400MHz DDR2 memory. The advantages of self built lab platforms with self designed chips are: a) All experience in the chips design process, the lower level software design and optimization and reference designs can be reused as our teaching resource and study cases; b) we know all the lower level details of these chips and related software, which means we can introduce the whole detail process of software-hardware co-design; c) we can customize the platform design to satisfy our teaching and learning requirements.



a)Mini4020 *b) HiveBoard*

Fig. 3. Self designed lab platforms.

Figure 3 shows two of our designed lab platforms: the Mini4020 and the HiveBoard. The Mini4020 lab platform is a very compact and low cost lab set for the students. With the on board 88MHz SEP4020 processor and 32MB SDRAM, students can run standard Linux 2.6.32 and MiniGUI on the Mini4020. A 3.5 inches TFT color LCD and touch panel module can be mounted on the top the main board. Students can use the on board USB device and host connector as well as GPIO pins to extend their own hardware.

The HiveBoard platform is a credit card size single board computer with 128MB 400MHz DDR2 memory. The main processor of HiveBoard is the SEP6200 high performance application processor which integrates an 800MHz UniCore32 CPU，a 2D/3D GPU and a 1080P VPU. To lower the cost, HiveBoard uses a SD card as its nonvolatile memory. Like the Mini4020 platform, HiveBoard can be easily extended by USB interface and GPIOs.

We designed lots of in course and out course labs, some of which are directly coming from our chip design and software-hardware co-optimization process, on these self designed lab platforms. Different from previously designed labs which are focusing on skills of how to use SDKs and libraries, we emphasize the relationships and interferences of hardware and software components in the system. Table I. lists some lab examples in the course of “Embedded systems”.

Table I. Some Labs in the “Embedded systems” course

Lab Name	Contents

Lab platform hands on	1. Learn how to use the IDE 2. ARM instructions and assemble language 3. C language compiling and linking 4. C call stack tracing and analysis (parameters transfer, return address, local variables, saved registers for the callter)
GPIOs and Timers	1. Using a GPIO to control a LED 2. Timer configuration and interrupt handler 3. Using a Timer to trigger a GPIO flopping and using a logic analyzer to measure the pulse width 4. Using a timer and a GPIO to output a square wave and analyzing the maximum limits of the wave frequency
DMA and LCDC	1. Confirmation of a DMA channel 2. Configuration of a LCD controller 3. Speed testing of memory copy using software and a DMA channel 4. Duo display buffers for the LCD 5. The influence of DAM to the LCD display
Design of a temperature sensing node	1. Using IIC or SPI to connect a temperature sensor and sampling in a given frequency 2. Displaying the temperature on the LCD in real time 3. Transmitting the temperature data to a PC by a UART
The performance influence of clock frequencies of CPU, Bus and DDR	1. PLLs Configurations of CPU, Bus and DDR 2. Set the frequencies of Bus and DDR to be constants, adjust the frequency of CPU and test the system performance using a benchmark program 3. Use the same scheme in 2, adjust frequencies of Bus and DDR and test the system performance
The optimization of memcpy() function	1. Learn how to test the speed of memory copy 2. Testing the speed of C version memcpy() 3. Testing the speed of 32 bit memcpy() using LDR/STR instructions 4. Testing the speed of memcpy() using LDM/STM instructions 5. Testing the DMA version of memcpy() 6. Testing the speed of memcpy() with and without Caches

To consolidate what they have learned in the courses and to encourage more students engaging in self learning, an annual embedded systems design contest (ESDC) in southeast university has been held since 2008. The contest gives each team, typically 3 students, a Mini4020 or HiveBoard platform and relevant trainings. Students are encouraged to use their creativities and imagination to push the limits of the hardware. Figure 4 shows some submitting designs. One of them try to use an 88MHz ARM720T platform to run a 3D Rubik's cube application while another use the SEP6200 platform to design a flight simulator game. Obviously, both designs need very systematic and deep understanding of software hardware co-optimization.

Fig. 4. Some students' designs in the ESDC based on the Mini4020 and HiveBorad platforms.

The ESDC has been organized for 7 times since 2008 and there are nearly 900 teams have participated this contest, including 76 teams we invited from other universities. Table II shows the summary information about each year's team information of this contest.

Table II. Teams information of the Embedded System Design Contests (ESDC) from 2008 to 2014

Contest Name	Time	Teams Registered	Teams Submit results	Teams win Awards	Teams from other Universities
ESDC 08	2008.4	109	50	20	4
ESDC 09	2009.4	136	64	20	14
ESDC 10	2010.4	150	85	25	15
ESDC 11	2010.4	142	49	30	4
ESDC 12	2012.3	129	84	49	12
ESDC 13	2013.3	108	68	37	8
ESDC 14	2014.3	113	74	33	19
SUM		887	474	214	76

IV. CONCLUTIONS

An embedded systems curriculum contains six courses has been developed in Southeast university. These courses cover main design levels from SoC design to application and system design and emphasize the process of software/hardware co-design and co-optimization. To encourage students learn lower details of co-optimization, we build our own lap platforms based on self designed SoC chips and organize embedded system design contest.

It seems that this new embedded systems curriculum has enhanced the integration of university education and corporate training. A good comparison between theortical knowledge and independent academic research is also obtained.

ACKNOWLEDGMENTS

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Construction of Mental Models in the Minds of Engineering Technology Students

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Abstract — Engineers are expected to apply the theoretical knowledge learned in the classroom in their practicing fields. An effective way to enforce theory is to include experiential learning. One approach of experiential learning is to correlate the labs with the lectures, where the laboratory experiments are being used as a continuation of the lectures. This paper presents three examples of experiential learning approach used in undergraduate studies.

Keywords— Experiential Learning, Demonstration Based Learning, Mental Models, Simulation Based Learning

Introduction

Due to limited resources and funding, large class size is very common in today's universities. Typically, students find it hard to ask questions in a lecture hall full of other students. Memorizing the theories seems to be the typical way to handle difficult concepts. Gallagher [1] observed that memorization, not understanding, is the most common approach to scientific knowledge in today's classrooms. After reviewing textbooks and exams, he found that today's education foster students to memorize scientific ideas; it does not encourage the students to learn how to apply these ideas. The School of Engineering Technology (SET) at McMaster University has adopted an experiential learning approach to actively foster learning. With an average lecture size of 60 students and lab size of maximum 20 students, almost all technical courses offered in a four-year bachelors program are delivered with both lectures and hands-on labs.

David Kolb's [2] experiential learning approach can be categorized into four phases: *concrete experience*, *reflective observation*, *abstract conceptualization*, and *active experimentation*. In the concrete experience phase students are introduced to the knowledge to be learned through active experiences such as lab sessions or field work. In the reflective observation phase, students consciously reflect back on the experience. They tend to ask a lot "why" questions. In the abstract conceptualization phase students form a theory or model of what is observed. In the last phase, students plan a series of experiments to test the effects of changing parameters on the theory or model.

The experiential learning approach used in the majority of the technical courses offered in the Automotive and Vehicle Technology program implies an integration of the theory with a practical component. The laboratory experiments, generally used to reinforce the knowledge taught during the lectures, are correlated with the theory. Students learn the theoretical knowledge in the classroom and apply it after a very short time during the following laboratory session.

The implementation of Kolb's experiential learning approach in three technical courses offered in the SET's Automotive and Vehicle Technology (AVT) program is exemplified in the following sections. The first example is related to a course with a high mathematical content. The second example describes the approach taken in a CAD course. The third example presents two ways of applying experiential learning approach in an automotive course.

Example 1: Experiential Learning Implemented in a Vibration Analysis Course

While mathematical models are often used to describe the physical world, using mathematical models alone is generally insufficient in making a strong impression on students' minds. To do this, and to allow future knowledge to be built upon, students need to be able to construct a "mental model" of the concept and be able to work with this model in their minds. However, the mathematical models are often very difficult to be visualized and worked with in one's mind. Experiential learning tools including in-class demonstrations, computer simulations and lab experiments, allow mathematical models to be converted into other forms that are much easier to see, hear, and touch. These experimental models are easier to remember then theoretical ones when a new concept is taught in class.

Vehicle Dynamics I is a vibration analysis course offered in the third year of the AVT program. The course starts with an introduction of the mass, spring and damping elements in a mechanical system, and their respective effects on the system dynamics in free vibrations. Then the idea of forced vibrations is introduced together with the concept of frequency response, base excitation and rotating unbalance. Towards the middle of the course, students are exposed to the concept of vibration control with emphasis on how to design the mass, stiffness and damping elements in a car to achieve a desired dynamic response. The last part of the course involves the idea of vibration absorber design and implementation in the field.

This Vehicle Dynamics course is delivered with 3 hours of lectures per week and 2 hours of lab every other week. The delivery of the course using David Kolb's [2] experiential learning model is described below:

Concrete Experience – To give the students some concrete experience as early as possible, this course is implemented with a lot of demonstrations in the classroom. For each new topic introduced to the students, there is one demonstration tool associated with the topic. For example, instead of simply reading from a slide what is the natural frequency and how mass is related to the natural frequency of a mechanical system, a wooden meter stick clamped on to a table with a C-clamp added onto the cantilevered-end is shown as a demo in class. The demo creates a concrete experience for the students. Seeing right in front of them how the added mass affect the oscillation frequency of the cantilevered system, a concrete mental model is established in the minds of the students.

Reflective Observation - To allow the freedom to observe and reflect students are asked to perform a lab experiment on a model vehicle equipped with an accelerometer (Fig. 1). There are 4 parts in this experiment. Parts 1 and 2 are scheduled for 1 lab period and Parts 3 and 4 for another. Part 1's objective is to measure the oscillation frequency of the vehicle under free vibration using an impact as an excitation input. The effects of the mass on the vehicle's natural frequency are also studied.

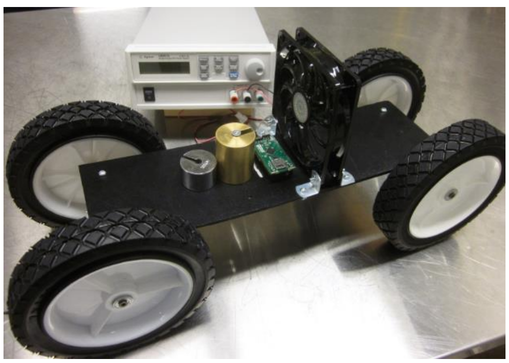

Fig. 1- Model vehicle to study frequency response

Part 2 is to determine the oscillation frequency and amplitude of the vehicle under forced vibration. A cooling fan with an unbalanced blade is mounted on the vehicle. By changing the input voltage, the speed of the fan will change and the output is measured by the accelerometer. The students experience the idea of "resonance" first hand when the input frequency is equal to the system natural frequency. By plotting the frequency response graph (Fig. 2) students will observe the effect of how the ratio of the input frequency and the system natural frequency could affect the vibration amplitude.

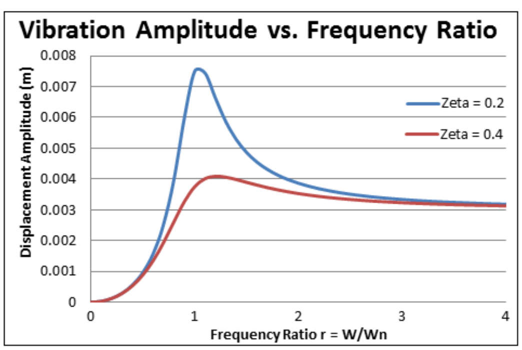

Fig. 2- Typical amplitude vs. frequency ratio graph

Abstract Conceptualization – By this time, the model in the minds of the students is no longer just a mathematical equation or a graph. A very concrete model is formed in their heads. In Part 3 of this experiment, the objective is to implement vibration control. Desired vibration amplitude to achieve at steady state under a range of fan speeds as inputs is given. Based on the theories covered in the lectures and the previous parts of the experiments, students need to re-design the model vehicle by calculating the change in the vehicle mass and/or the stiffness required to achieve this goal.

Active Experimentation – In Part 4, the students are challenged to implement their new design and measure the new output amplitude. A common mistake that students make is that the damping factor, zeta, of the system is affected by the change in mass and/or stiffness; however, it is often overlooked in the calculation. The student will experience this first-hand after they have implemented their design changes. Having a physical hardware in the lab allows the students to exercise active experimentation. They could evaluate their design again and implement further adjustments. In writing the lab report, the students are also asked to discuss the pros and cons of ways of changing the mass and stiffness of their system in real life applications. It is important to relate the experience in the lab to real life scenarios for a complete learning cycle.

Results – The experiential learning approach allow students to visualize the theoretical concept through the demos shown in class. Students understand the concepts and are able to see their application in everyday life.

Example 2: Experiential Learning Implemented in an Advanced CAD Course

The main learning objective of the Advanced CAD course offered in the AVT program is to create complex solid-model assembly, and simulate their kinematic motion on a computer. CATIA software is used for this purpose for 8 weeks, with 4 hours per week. The layout of the course is split as follows: introduction to CATIA software interface (2 weeks), in-class exercises of assembly-kinematics (2 weeks), group project (4 weeks, 5 students per group). The application of David Kolb's experiential learning approach is described below.

Concrete Experience – At the beginning, students are taught the interface of the CAD software. Pictures and videos from past projects are shown to demonstrate software's capabilities. Using the in-class projector, students are shown menu commands and step-by-step instructions for creating and constraining sketches using dimensional and geometrical tools. Individual part models are created from sketches using feature tools (Fig. 3).

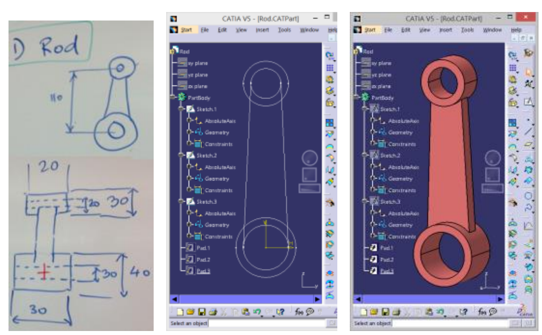

Fig. 3 - Example of part modeling process: dimensions, sketch constraints, and part model for an engine part (rod).

Reflective Observation – An exercise (Fig. 4) of assembly and kinematics task is started in class, based on parts previously created. Several techniques for constraining parts in an assembly are explained, and their benefits and drawbacks are discussed. Once comfortable with the CAD software, students are asked to complete the rest of the exercise under supervision, and observe what methods work better for the remaining of the assembly.

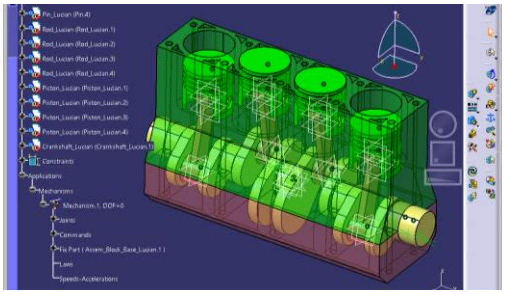

Fig. 4 - Kinematics exercise: simplified car engine with crankshaft, pistons, pins, rods, block, and oil pan.

Abstract Conceptualization – Students are asked to form groups and apply their CAD knowledge to a complex project of their choice. The project must have few moving parts and a certain degree of complexity, but the topic is free. To complete the project, students must first create a mental model using the CAD concept taught in class.

Some examples of past project topics include: bicycle, power drill, chainsaw, lawnmower, car engine, toy-helicopter, RC-car, motorbike, car suspension, steering mechanism, gearbox, differential, mechanical clock, etc. From our observation, many students prefer topics for which they have a real-life replica whose components can be taken apart and measured for modeling.

Active Experimentation – Students are now challenged to think how the modeling concept taught in class can be implemented to their own project. Each physical part must be inspected and planed for the proper modeling technique. Other challenges: parts measurement to fit final assembly model; sharing of CAD files among group members, group communication, and meeting project deadlines.

Results – We have achieved very good results with this type of project in our CAD course (Fig. 5). Students simply loved the challenge, and very often they spent many extra hours going beyond the actual project requirements.

Fig. 5 - Example of CAD project modeling results: Remote controlled toy-helicopter (CATIA model)

Giving students the freedom to choose their own project topic seems to be one of the key ingredients for a successful experiential learning in our CAD course. By asking students to complete a job that is related to their skills, or hobbies, they seem more engaged and determined. In addition, a “pre-model” already exists in their minds about how the assembly (to be modeled) works in real-life, making the completion of the modeling project more appealing.

Challenges – Implementing experiential learning is not easy, and it should be carefully considered. Course refinement may take longer than expected. Course development and preparation requires effort and creativity from the instructor.

Open-concept projects are particularly challenging for marking. If students are allowed to choose their own topics, evaluating their work and individual contribution to the project becomes more difficult. Some students may choose a more difficult project with many parts, thus having to sacrifice the level of detail of their modeled to complete the project in time, while still achieving great results. Others may choose a simpler project with fewer parts but they may decide to spent more time to refine the models of the parts, or expand the kinematics simulation.

In such a case, marking scheme should be more general and it should account for a combination of several factors such as project complexity, quality of mode, and perhaps the degree of completeness. A good grade should still be assigned if some (not all) of these attributes were properly addressed.

Example 3: Experiential Learning Implemented in an Alternate Vehicle Power Systems Course

One of the contemporary approaches in automotive education is related to modern propulsion systems for ground vehicles. SET offers a third-year Alternate Vehicular Power Systems course that covers this topic with an experiential learning approach. The course deals with the fundamentals, theoretical bases, and design methodologies of electric vehicles (EVs), hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and fuel cell vehicles.

The course comprehensively covers vehicle performance characteristics, configurations, control strategies, and design methodologies. It includes drive train architecture analysis, EV, HEV and PHEV configurations, electric propulsion systems, series/parallel/mild hybrid electric drivetrain design methodologies, energy storage systems, regenerative braking, as well as fuel cells and their applications for ground vehicles.

Based on academic load constraints, the Automotive and Vehicular Power Systems course is offered with three lectures and three lab hours every other week. Due to the low number of weekly practical hands-on labs, the four phases of Kolb’s [2] experiential learning approach are applied in two ways. For concepts with a medium complexity, Kolb’s phases are applied during the lab component of the course. For concepts with a higher complexity, a separate design course is used to apply the knowledge taught in the Alternate Vehicular Power Systems course.

Concrete Experience & Reflective Observation – Converting a vehicle with internal combustion engine to an EV is a medium complexity example of knowledge taught in the course and applied during the lab. During the lectures students learn the theory related to modern batteries and electric motors and watch short videos related to practical implementation of EVs. During the first lab students have a concrete mental model developed with two EVs. They observe the different approaches used to install the components needed to propel the vehicle and start reflecting on the practical solutions. Some students are able to refer back to the theory while some others are helped by the lab instructor with hints that make them think and find answers to their questions. Although short in duration, these two initial phases of Kolb's experiential learning approach are essential in the conceptualization and active experimentation phases that will follow.

Abstract Conceptualization – An important set of labs is related to defining a concept for an EV, designing the propulsion system, manufacturing its components, implementing the concept, and testing the vehicle. Students start with a small road vehicle or with a go-kart equipped with an internal combustion engine. To further develop their mental models, the students are asked to conceptualize a propulsion model able to propel the EV with a reasonable speed.

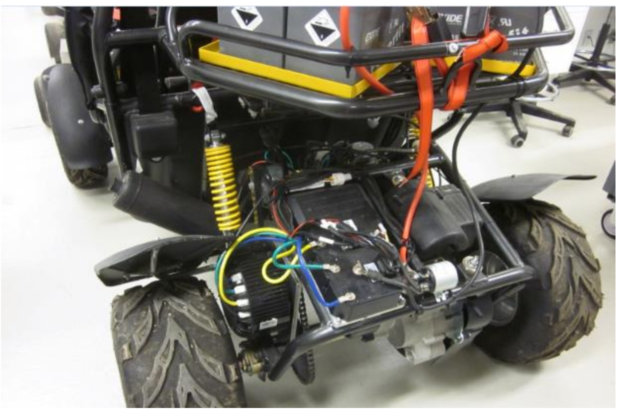

Fig. 6 –A HEV used in the Alternate Vehicular Power lab

Active Experimentation – After brainstorming various ideas, the class is divided into several groups, each group having a different task. One group is responsible for generating the specifications, collecting data related to the vehicle, performing power and torque calculations, and defining the battery and motor requirements for their vehicle. And the second group is in charge of designing the mechanical components needed for connecting the motor to the vehicle propelling shaft, while another group is in charge with manufacturing the mechanical components. The members of the groups vary from week to week to ensure that all students have a task during the entire lab time. Although the assembly of the electrical propulsion systems for the EV (Fig.6) is done in groups, the final road tests, generally done in the parking lot, together with speed, current and voltage measurements are done by all students. At the end of this active experimentation phase, the students are asked to write a technical report that correlates the theory learned in the classroom with the practical knowledge gained during the labs, to suggest refinements that would improve their design, and to discuss about the experiential learning approach that they experienced in this course. This reflection exercise strengthens the mental models in the minds of the students.

Complex designs and control strategies for EV and HEV generally include mechatronic devices used in the control and propulsion of these vehicles. The theoretical knowledge can be applied in open-ended student designs for a capstone course. In a two-semester design course, scheduled after the Alternate Vehicular Power Systems course, students use the same phases defined by Kolb in his experiential learning approach but at a different depth. The main outcome of the capstone course is to design, implement and test a practical automotive application, and to write a technical report.

An example of knowledge taught in the Alternate Vehicular Power System course that is practically applied in the capstone project course is an electronic differential. A group of three students is asked to brainstorm ideas to define an open-ended design project that applies the previously taught knowledge. They go through all the steps of the engineering design process: define the problem, do a background research, specify the design requirements and the constraints, brainstorm for possible solutions, explore possibilities, select an approach, develop a prototype, test the solution, perform design changes to improve the prototype, repeat the design–test steps until the solution meets the requirements, and communicate the results through a technical report.

The prototype development is just one phase of the engineering design process, but often it is the most complex and time consuming. Although the initial phases of the design process are performed by the entire group, the tasks involved in the prototype development step are split between the group members. Generally, one of the members of the group is in charge with the initial CAD solution and with the successive design refinements, one member is in charge with the mechanical components including CAM and mechanical assembly, and one member is in charge with the electrical and electronic components, with microcontroller programming, and with the entire control strategy. Each member of the group has the responsibility to identify issues related to their field and to suggest solutions that will improve the prototype. By building a prototype, the active experimentation phase of Kolb [2] is implemented, and the mental model of how to do a design project in the minds of students can be fully developed.

Conclusions

Mental models are found to be more concrete when constructed using the experiential learning approach. If properly implemented, experiential learning can improve the learning outcomes of students in various courses. By encouraging students to make use of their particular skills when applying the theoretical knowledge into practice, it can trigger the passion of students for learning.

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Teaching Interdisciplinary Engineering and Science Educations

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***Abstract*— In this paper we study *the challenges for the involved teachers who plan and implement interdisciplinary educations. They are confronted with challenges regarding their understanding of using known disciplines in a new interdisciplinary way and see the possibilities of integrating disciplines when creating new knowledge. We will address the challenges by defining the term interdisciplinary in connection with education, and using the Problem Based Learning educational approach and experience from the engineering and science educational areas to find the obstacles. Two cases based on interdisciplinary curriculum are used to find the problems. The conclusion is that teachers have to develop understanding of how to integrate their expertise in a new interdisciplinary curriculum. Furthermore they have to be aware of their knowledge profile. Teachers also need to use resources to find a common goal and understand how different expertise can contribute to an interdisciplinary education*.**

Keywords—Interdisciplinary educations – PBL – Teacher qualifications – Engineering and Science

I. INTRODUCTION

During the last century it has been obvious that the global problems are more and more complex and call for problem solvers with educational backgrounds who can meet these challenges [1]. To meet the challenges many educational institutions have started interdisciplinary educational programs [1], but definition of the concept "interdisciplinary" is still very much needed [2] for teachers as well as for students. Interdisciplinary educations are especially a challenge for the involved teachers who traditionally have a background within single disciplines, and therefore need to develop new pedagogical and didactic skillsets. Another challenge regarding teachers and students is to establish a new identity within the concrete interdisciplinary educational concept. In this paper we will address these problems by defining the term interdisciplinarity in connection with education, and using educational theories and cases from the engineering and science areas to find the obstacles. The overall question is how to define and understand the interdisciplinary education concept. Another question is related to the planning and implementation of interdisciplinary educational approaches in practice.

How is it possible to integrate the interdisciplinary concept in a curriculum? What are the related problems for especially the planners and the teachers who will be part of the new educations and who will have to carry out the teaching in practice? We will use the ideas and experience from two interdisciplinary educations; Lighting Design [3] and Media Technology [4] as examples of manning strategies. The examples are at different stages regarding planning and implementing of the educations.

The paper will describe different approaches to define interdisciplinary studies, and connect this understanding to the pedagogical approach. We are focusing on Problem Based Learning – PBL - , as this pedagogical approach seems to have the needed factors to integrate different disciplines [5, 6], and we are using the interdisciplinary education; Media Technology to illustrate the connected competence profile. Finally we will present and discuss the main findings.

II. INTERDISCIPLINARY EDUCATIONAL APPROACH

In recent years a number of interdisciplinary educations have been developed worldwide especially in HCI and related fields [7]. However, it is still a challenge to design an interdisciplinary curriculum, which at the same time is coherent and progressive [8]. Many interdisciplinary educations are merely a combined effort of putting together different competences from several faculty members. When starting planning an interdisciplinary education it is important for the planners to have a fruitful cooperation and a common understanding of the terms. Within e.g. HCI it has been a challenge to find the core competences in a curriculum which has to contain elements from engineering as well as human factors. As an attempt to bridge the gap, Pausch and Marinelli [9] describe how they in their HCI Master education started by teaching basic programming to artists, and humanistic subjects to computer scientists. However, this solution did not prove to be ideal. Instead, they preferred to mix the different profiles during students project work.

The terms *interdisciplinary* and *trans-disciplinary* are often used interchangeably. In this paper we adopt the definition proposed by Meeth in 1978 [10] who by observing and analyzing the existing confusion is defining what an interdisciplinary education is. Meeth proposed a hierarchical classification, illustrated in Figure 1. At the bottom he placed intra-disciplinary studies, i.e., studies composed of single disciplines. At a higher level we find cross-disciplinary studies, i.e., studies in which one discipline is viewed from the perspective of another. An example of a cross-disciplinary study is the study of the physics of musical instruments. Cross-disciplinary studies are relatively easy to establish, since they allow faculty members to remain in and use their own disciplines. At the next level he placed multidisciplinary studies, i.e., the juxtaposition of disciplines, each offering their own viewpoint, but with no attempt of integration. One level higher shows interdisciplinary studies, which attempt to integrate different disciplines in a coherent and harmonious curriculum of several disciplines which allow solving particular problems. According to Meeth, the highest level of integrated studies is transdisciplinary studies. Such studies go beyond disciplines, since they start from a problem and, using problem solving approaches, they use the knowledge of those disciplines which can contribute to the solution [10]. Therefore while interdisciplinary studies start from a discipline and develop a problem around it, trans-disciplinary studies start from a problem and find the related disciplines which facilitate solving it.

As also argued by Pausch and Nicolescu [12], trans-disciplinary studies are hard to design, since they require highly prepared and intellectually mature faculty members. Interdisciplinary and cross-disciplinary or multi-disciplinary are often used without considering their meaning. It is important to have a clear definition and understanding of those words when trying to establish a common understanding of a new education with a new combination of disciplines. In this paper we will use the definitions proposed by Meeth in 1978 when discussing how to plan and teach a curriculum.

5. Transdisciplinary studies
4. Interdisciplinary studies
3. Multidisciplinary studies
2. Croossdisciplinary studies
1. Intradisciplinary studies

Fig. 1. Representation of the hierarchical educational structure as proposed in Meeth [10].

The remaining question is which pedagogical approach can support and ensure the integration of the content in an inter-disciplinary and cross-disciplinary education.

Our presumption is that the Problem Based Learning approach (PBL) represents an ideal framework to design an interdisciplinary education close to being trans-disciplinary in the sense defined by Meeth [10], where transdisciplinarity and interdisciplinarity is viewed as the ability to define a problem and the relevant disciplines which allow solving it.

III. Problem based learning approach

All engineering educations at Aalborg University are based on the Problem Based Learning (PBL) pedagogical approach and have been used as a main pedagogical approach to train faculty members to evolve from cross-disciplinary and multidisciplinary to interdisciplinary and trans-disciplinary understanding of the study. PBL becomes interesting when a variety of disciplines need to be incorporated to address a complex problem [11].

PBL support students to work with a problem and to structure problems in such a way they will be able to integrate and apply knowledge from different disciplines. This allows students to see connections among disciplines and promote the carryover of knowledge from one discipline to another. In this situation, PBL facilitates transdisciplinarity, since students are exposed with a problem, and need to find the relevant disciplines and connections among them which allow solving the problem. Most of the problems addressed by students in the different semesters are trans-disciplinary by nature, since students start from a given theme, finding a problem to solve, and use several disciplines to address it and solve it – of course always facilitated by a teacher. Knowing the PBL strategy for students' projects has been the best qualification for teachers connected to interdisciplinary educations.

IV. The teachers challenges

In this chapter we will use the experience from 2 different interdisciplinary educational approaches;
Lighting Design [3]
Media Technology [4]
The approaches have had very different circumstances and ideas, but the main theme for them is that they see the possibilities in establishing interdisciplinary educations based on the arguments that the problems connected to their research and teaching areas are so complex that an interdisciplinary approach is necessary.

1. *Lighting design*

This education integrates architecture, civil engineering, lighting technologies and humanities. When planning a new interdisciplinary education the understanding of the terms and language is very important. The biggest challenge in the planning phase of a new master in "Lighting Design" was to establish a common vision and goal among the teachers from different faculties involved in the planning, and get them to see how their different expertise can generate synergy. It took a lot of time to get a common language and to understand each other's expertise as well as finishing the discussion about the value of each teacher's expertise in the new education. Most of the teachers in the planning group had many years of experience from their respective research areas and educations, so to get this common understanding was a very hard barrier to overcome. According to the head of the planning group, the PBL pedagogical approach has been a key factor during the process, and will be the cornerstone which can connect the faculty and the ideas in further developing of the education. According to the teachers it is still difficult to see the overall curriculum and find your own teaching "you have to establish a new identity". After one semester the faculty is still struggling with set-backs among the teachers using their expert knowledge without any connection to the new curriculum and study plan.

2. *Media Technology*

Media Technology started 10 years ago, and was based on an inter-disciplinary approach. The challenge was to move away from a multidisciplinary education towards a coherent inter-disciplinary one with a defined identity. This goal was addressed in different ways. A small group of very motivated teachers were the key planners, and a lot of newly educated teachers were connected to the education.

First of all the key competences for the education was identified from a technical and a humanistic point of view: new media technologies and the human senses. The teachers liked the idea, but had difficulties to understand each other's expertise and understand how it could be integrated in one curriculum. The education was started, so the teachers needed to find out how to teach according to the new curriculum. They needed to find their common teaching mode.

Part of the PBL approach is that students work in groups doing a project. Each project starts with a problem within a semester theme, but formulated by the students. Each project group normally has one or two facilitators/teachers connected.

One way that proved to be quite effective was to create teams of teachers connected as project facilitators for student's project work, each teacher coming from a different background within the complex of curriculum areas. Each member of a team has to be present at every meeting with the student group (once a week), and were required to be prepared in all components of the project.

The teachers got training in the Problem Based Learning pedagogical approach at the same time they were using it [13]. The teams of supervisors evaluate the students at the end of the semester. This approach is particularly beneficial for those faculty members previously trained in single-disciplinary educations. Obviously the choice of the faculty members working is fundamental when developing any education, but it is of special importance when developing and planning an interdisciplinary education.

Established and long running educations usually hire faculty members which fit into the teaching and research plans of the department. In newly created interdisciplinary educations where the curriculum is continuously questioned, two different approaches can be used when hiring faculty members. The first approach consists of designing a curriculum and then hiring faculty members with qualifications needed. The second approach consists of hiring faculty members with different backgrounds, and then allows them to design different courses which together will form the new curriculum.

The advantage of the first approach might be that it provides a more coherent education, but the different faculty members will feel they do not completely own the education. In the second approach there is a high risk of having a multidisciplinary education in the sense described by Meeth [10], i.e., simply a juxtaposition of disciplines each offering their viewpoint but not real attempt of integration.

Establishing a common understanding and acceptance of the different expertise, and be able to see the benefit of integration is very important. Training teachers in teaching using interdisciplinary approach is another important issue. Finally to understand that once the education is planned and decided upon, the development of the faculty is a never ending process.

V. EXAMPLE: THE MEDIA TECHNOLOGY PROGRAM – UNDERSTANDING STUDENTS KNOWLEDGE PROFILE

The study plan for the Media Technology education has been changed several times, and each new version is an improvement – and it is still under revision.

It has been very important that the teachers understand the student's competence profile and relate it to their own profile.

The PBL approach means that each semester has a theme which defines the frames of the student's projects, and the semester courses as well as students projects have to be directed towards this theme. The competence profile of Media Technology students can be seen as a T, which is also known from the d.school [16].

The knowledge and experience connected to the academic competencies mentioned in the study plan and the knowledge related to courses and students work in teams making projects are: project management, learning abilities, communication skills, cooperation etc. combined with an understanding of Media Technology in general establish the horizontal line in the T, and we call them Media Technology process competences.

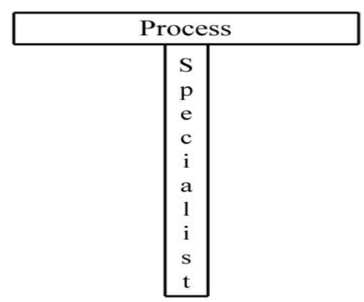

Fig. 2: The T-shape model illustrates the Media Technology profile [16].

The vertical line illustrates the specific Media Technology competences, which can be rather specialized depending on the the student's choice of specialization and the level of education. In an interdisciplinary education where you work with integration of disciplines, the importance is the ability to transfer methods and knowledge from one discipline into another, and this is also one of the process competences. Interdisciplinarity overflows the disciplines, but its goal still remains within the framework of the combined disciplines, even there will be the capacity of of generating new disciplines [14].

The T-shape can differ. The horizontal line can be shorter or longer related to the broad knowledge, experience and understanding of the process competences. The vertical line can also be shorter or longer related to how deep the specific Media Technology specialization is (see fig 3). We know that Master Graduates either have a broader or longer vertical line depending on development of their specific knowledge area. For example, some Master graduates are very specialized within sound and related communication aspects, and some are broader in their knowledge area using sound, computer graphics and virtual reality. The challenge for the students is to find the balance of the T related to the goal of the education. The faculty members also need to understand their special knowledge as part of the T- model. They have to be aware of their special expertise as well as their broad knowledge so they keep their balance as well. Some faculty members are so specialized that they cannot relate to and understand others' expertise when working in a cross disciplinary field (see fig. 3). Other faculty members are so eager to learn about the broad perspective in a way that their vertical line will become too short, and they lose focus on their own expertise. One cannot work in a cross-disciplinary environment if (s) he doesn't have enough expertise with which s (he) can contribute. So faculty members as well as students have to keep the balance of the T when developing their knowledge and expertise [9, 17].

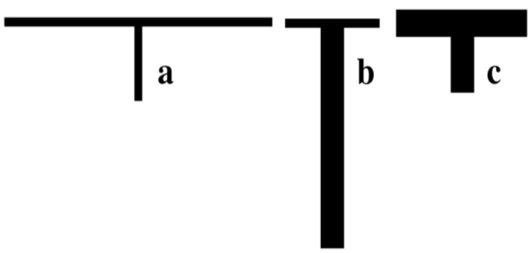

Fig. 3: The different T-shape models illustrate how the competence profile can change.

The study plan is developed with the aim to support the T-shape competence profile, and the PBL approach is a necessity when using the competences in action meaning when the groups of students are making their projects and prototypes. The challenge for the teachers and students is to find the balance of the vertical as well as horizontal line.

VI. Conclusion

When planning and implementing an interdisciplinary education it is important that the involved teachers understand the concept of interdisciplinary education as well as seeing a common vision and goal. It is also important to get sufficient knowledge of the different disciplines needed for the planned education and to respect and find out how to use each other's expertise which is the basis for understanding how different expert's knowledge can be used in an integrated way when trying to solve a complex problem. The teachers have to develop a new skill-set. This part can be difficult and time consuming, but is important when establishing the common integration of teacher's expertise. Understanding the T-profile and how it can be used in an interdisciplinary education has proved to be useful for the teachers understanding of the teaching challenges as well as of the own expert development. Finally it seems that a pedagogical approach which is based on PBL where students are allowed to work with interdisciplinary problems seems to be very fruitful for teachers when implementing interdisciplinary educations.

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Video Games as a Pedagogical Tool for Teaching Computer Programming

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***Abstract*—The purpose of this study is to measure the success of using a social video game as a pedagogical tool in instructing basic computer programming concepts in a first year programming course. Results show that the game is able to teach students basic programming concepts. Furthermore, in some cases, game participants outperform non-participants. On the final exam, all of the statistically significant ($p < 0.05$) comparisons (42% of the relevant questions) showed a performance improvement of game participants, with a maximum grade improvement of 41%.**

***Keywords*—educational video game, cooperation, competition**

I. Introduction

Computer programming is a complex subject that cannot be taught through conventional lecturing and explanation alone. The practical nature of programming requires that those new to this discipline must engage in hands-on experimentation to become skilled in this field. First year engineering students that are unmotivated to study programming on their own often find themselves struggling in their computer programming courses. A cooperative and competitive tablet video game, called Space Race, was designed to engage students in the course material. The cooperative nature of Space Race encourages students to teach each other programming concepts, while the competitive aspect of the game pushes students to review their course material. In this paper, the effectiveness of the game is evaluated by comparing student performance before and after game play. Also, the performance of game participants versus non-game participants is contrasted.

II. Literature Review

While game-based learning can be highly effective, there is still a lack of empirical evidence to suggest that its application in software engineering or computing is effective. Game-based learning here refers to the use of games as a tool to teach programming; it does not refer to the *development* of games as a method of teaching programming.

Most of the research that has been completed does not definitively compare the effects of game-based learning to more traditional methods. Moreover, almost none of the research has evaluated whether the programming knowledge acquired from the game is transferable to contexts outside of the game and none of the games employ collaboration or teamwork in gameplay. In fact, many games have been proposed by researchers, but they have either not been implemented, or not investigated [1]. Those that have been investigated have been tested on very small population sizes. Table I lists some games that have been proposed or implemented by different researchers for implementation in software engineering or computer science education.

TABLE I. Games Proposed for Implementation in Software Engineering Education

Author(s)	Game(s)	Programming Topics	Evaluation
Rathika Rajaravivarma (2005) [2]	Number and Word Games	basic programming skills	No evaluation
Wen-Chih Chang, Yu-Min Chou (2008) [3]	"*Bomberman*" computer game	introductory C programming language	No evaluation
Mathieu Muratet et al. (2009) [4]	Real-time strategy game	basic programming skills	Evaluation proposed-results not published
Emily Oh Navarro, Andre van der Hoek (2005) [5]	SimSe-Interactive Simulation Game	software engineering process (project management)	No evaluation
Charles Wesley Ford, Steve Minsker (2003) [6]	"*TREEZ*" computer game	tree traversal techniques and iterative/ recursive traversal algorithms	No evaluation
Andrew Martin (2000) [7]	Simulation game	information systems development	No evaluation
Marina Papastergiou (2009) [8]	LearnMem1 (game), LearnMem2 (software)	basic computer memory	pre and post-test for students(N=88), game more effective, no long term evaluation
Kazimoglu et al. (2012) [9]	Program Your Robot	basic programming skills	no quantification, qualitative feedback from students (N=25)
Ju Long (2007) [10]	Robocode	Java or .NET framework	qualitative survey from diverse population(N=83), no quantification

III. Game Design

A. Design Goals

Two primary goals were set to maximize the effectiveness of the game by motivating students to engage with the content:

1) Cooperation between students to reinforce learning of programming concepts.
2) Competition between groups of students to motivate learning.

B. Game Overview

Space Race is a multi-player Android tablet game that was developed for this research project. Every player must have their own Android tablet to play Space Race. The game is played in teams of four and it features cooperation amongst team members and competition between teams. Players progress through a level by correctly answering or executing a series of Python-based questions or instructions served by the game. Game performance is dependent upon the time it takes to complete the instructions in a level; the shorter the time, the better the performance. The best time for each

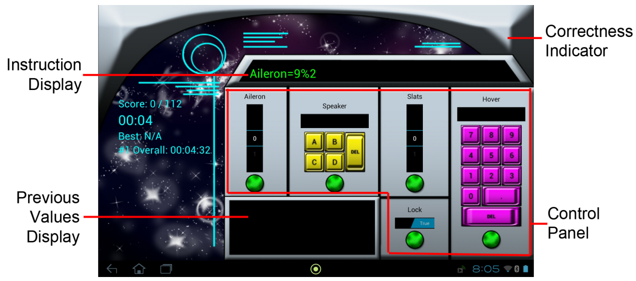

Fig. 1. Game Screen for Level 2

team is recorded per level on a public leaderboard that players are able to access through the main menu in the game.

The game is comprised of four levels and each advancing level introduces new programming concepts that rely on a firm understanding of concepts taught in the previous levels. The game mechanics between Levels 2, 3, and 4 are very similar, while the game mechanics of Level 1 are different. The gameplay of Level 1 is very similar to that of a multiple choice quiz game. Levels 2, 3, and 4 was inspired by **Spaceteam**, a cooperative Android and iPhone game developed by **Sleeping Beast Games 2012**© [11]. "Cheat Sheets" that outlined the basic programming concepts introduced in each of the levels were provided for students for Levels 2, 3, and 4. Since Level 2, 3, and 4 are very similar and more involved, the game mechanics of Level 2 will be described briefly.

The game screen for Level 2 can be seen in Figure 1. It includes an instruction display, control panel, previous values display, and correctness indicator. Every player will have the same controls on their control panel, but all the controls will have unique names. That is, the control names are never duplicated; either on one panel or across different panels. In addition to the touchscreen controls, players can also trigger a game event with a shake motion. This shake motion is, used to acknowledge a Python exception.

The objective for this level is for players to execute all the instructions in 4 different programs in the shortest time possible. Before the game begins, each player is randomly assigned a unique program from four available programs. During the game, the players are served one instruction at a time from their assigned programs. A new instruction is served to a player when the previous instruction has been correctly executed. Instructions indicate the value that controls on the control panel should be set to. It is possible for a player to receive instructions for a control on their own control panel, or for a team member's control panel.

For research purposes, the game has been designed to ensure that every player on the team receives the same learning experience. By the end of the level, all the players will have given and received a set of instructions that covers the same range of topics as everyone else.

IV. Participants

The study was conducted with voluntary participants from the first-year engineering student population of McMaster University. Specifically, these 485 students were enrolled in ENG 1D04-Engineering Computation, a 12 week introductory programming course. This group of participants was further divided into two groups: one control group that did not play Space Race and one experimental group that did play Space Race. Since students were not required to play all four levels, the number of participants in the experimental and control group varied across the four levels. Table II shows the number of participants in each level of Space Race.

TABLE II. Space Race Participation Numbers

Level	Experimental Group	Control Group
1	236	249
2	214	271
3	194	291
4	190	295

V. Game Reception and Feedback

This section will provide an overview of the survey results that indicate students' affinity and perceived effectiveness of Space Race. Overall, it appears that a large majority of the students enjoyed playing the game with at least 82.22% students agreeing with the statement "*I enjoyed playing the video game*" on the survey across all the levels.

From the survey, students felt that the game needed more feedback response to teach students concepts instead of simply confirming correct knowledge. Even though there was a lack of feedback from the game, which prevented the game from directly teaching students concepts, it certainly created multiple opportunities for team members to teach each other new concepts.

An instructor was present while the students were playing the game and when a team failed to execute an instruction correctly after much discussion, they would raise their hands to ask for additional assistance. This allowed the instructor to gain a better understanding of what the students did not understand. Moreover, it helped the students identify concepts that they were not familiar with. Finally, although the game cannot teach students directly, it encourages students to ask the instructor questions when they do not understand.

Students provided the following feedback with regards to cooperation in Space Race:

- "*I really enjoyed the cooperative aspects of the game because it does a tremendous job of encouraging teamwork and sharing individual knowledge for the benefit of a common goal...*".
- "*When we were stuck on a question, the team would offer suggestions and we would get through the question together. This was helpful when questions were hard and especially when the player did not know the correct answer on their own.* "
- "*My team members helped me to understand the various tools being presented and helped to clarify things I did not quite understand.*"
- "*I really liked the cooperative nature of this video game. Individually, we may have struggle with the concepts; but as a team, we conquered them.*"

The quotes given above highlight how cooperation influenced gameplay in Space Race and facilitated learning.

TABLE III. PRE AND POST QUIZ MCNEMAR'S TEST RESULTS

Question	Pre Correct(%)	Post Correct(%)	Delta Correct (%)	McNemar's Chi-Square Statistic	P-Value	p<0.05?
LEVEL 1	**N= 230**					
1	17.83	40.87	23.04	44.59	0.000	Yes
2	26.09	30.43	4.35	1.79	0.181	No
3	71.3	69.13	-2.17	0.36	0.547	No
4	39.57	46.96	7.39	6.42	0.011	Yes
5	19.13	60	40.87	83.36	0.000	Yes
LEVEL 2	**N= 188**					
1	96.28	95.21	-1.06	0.33	0.564	No
2	23.94	28.72	4.79	3.24	0.072	No
3	26.6	30.85	4.26	2	0.157	No
4	53.19	54.79	1.6	0.36	0.549	No
5	69.15	85.11	15.96	22.5	0.000	Yes
LEVEL 3	**N= 171**					
1	66.67	73.68	7.02	5.14	0.023	Yes
2	30.41	46.2	15.79	13.75	0.000	Yes
3	66.08	81.29	15.2	16.1	0.000	Yes
4	90.06	90.64	0.58	0.04	0.835	No
5	17.54	82.46	64.91	98.57	0.000	Yes
LEVEL 4	**N= 167**					
1	79.04	92.81	13.77	17.06	0.000	Yes
2	61.08	69.46	8.38	6.53	0.011	Yes
3	49.1	59.88	10.78	9	0.003	Yes
4	72.46	85.03	12.57	13.36	0.000	Yes
5	31.14	61.68	30.54	40.02	0.000	Yes

VI. EDUCATIONAL EFFECTIVENESS

A. Pre and Post-Quiz Results

The pre and post quizzes are identical and they are completed by the students before and after every level of gameplay. Solutions to the quiz are not offered after completion of the pre or post-quiz. Table III shows the percentage of students that answered correctly on the pre and post-quiz. The table also includes the number of students that successfully completed the pre and post-quiz questions for each level (indicated by N). This number may be less than the number of students that actually played and completed that level of Space Race because some students were unable to submit the post quiz due to technical issues. The quiz data, both pre and post, for these students has been eliminated from the results.

McNemar's test was chosen to verify the significance of the differences between the pre and post-quiz results for each question. The results of McNemar's test can be seen in Table III. The table shows that 65% (13/20) of all the results are significantly different at a level of 0.05 (alpha). Additionally, all of the results that are significant are cases where the proportion of students that were correct in the post-quiz exceeded that of the pre-quiz (positive delta correct). On the other hand, all of the negative delta correct results were not statistically significant. This suggests that Space Race either improves or has no effect on students' knowledge of computer programming concepts.

The questions that yielded insignificant improvements could be explained by question design. Some questions were either too easy; most students understood the concept before playing Space Race. Other questions may have required too much abstraction from the knowledge obtained from the game to answer correctly.

B. Final Exam Results

The final exam in ENG 1D04 is completed by the entire student population and thus, differences in performance on the exam between the control and experimental group can be used to show that Space Race has caused different levels of learning. Furthermore, since the majority of exam questions are designed by the instructor of ENG 1D04, and not by the researcher, the questions should have a minimized bias. As a result of this, the exam can also indicate whether the concepts learned in Space Race can be applied to a context that is unrelated to Space Race. Finally, since the final exam takes place at the end of the term, 8 weeks from when Space Race was last played, it can serve as an indicator on the retention of material learned in Space Race.

Since members of the experimental group volunteered to play Space Race, it is important to first assess whether these individuals were pre-disposed to excelling in ENG 1D04. That is, there must be confirmation that there was minimal self-selection bias so that causation can be attributed to Space Race rather than a biased sample population. To do this, a combination of the Math 1ZA3 (Engineering Mathematics I) and Physics 1D03 (Introductory Mechanics) exam marks for each student were used to benchmark student abilities. Both of these courses were completed the term previous to ENG 1D04. Math and physics marks were chosen as indicators because research has shown that misunderstandings in physics, mathematics, and computer programming display strong commonalities with one another. These misunderstandings can arise as the result of parallel or identical causes that occur in each domain [12].

Both the control and experimental group had a normal distribution of scores. As such, the t-test was performed with the null hypothesis that the two independent samples, the experimental and control group, have the same distribution. The results of the t-test can be seen in Table IV for each level. It can be seen that the p-value for all four levels is well above 0.05. Consequently, the null hypothesis cannot be rejected. This suggests that there is very weak evidence the distribution of scores between the experimental and control group are not the same. This conclusion suggests that there is minimal self-selection bias in the experimental and control group thus strengthening the argument that any differences in performance between the two groups can be attributed to the influence of Space Race.

TABLE IV. T-TEST RESULTS FOR COMPARISON OF EXPERIMENTAL AND CONTROL GROUP SCORES

Level	t-statistic	p-value
1	0.5214	0.6024
2	1.2440	0.2142
3	1.0046	0.3157
4	0.8312	0.4064

Not all of the questions from the final exam were analyzed. This is because only some of the questions involved material that was taught in Space Race. After the questions were chosen, each question was assigned one or more levels of Space Race according to its relevance to the material covered in those levels. This is necessary because it assists in determining which students belong to the experimental and control group when comparing results between the two populations. A student is considered to belong to the experimental group if they have played either one of the levels that have been assigned to that question.

The final exam results of the experimental and control group can be seen in Table V. The Chi-square statistic was used to test the significance of the difference of results.

TABLE V. FINAL EXAM CHI-SQUARE TEST RESULTS

Question	Levels	Experimental Group Correct(%)	Control Group Correct(%)	Delta Correct (%)	Chi-Square Statistic	P-Value	p<0.05?
4	1	51.83	51.08	0.76	0.00	0.965	No
5 (L3Q5)	3 4	77.56	36.20	41.37	61.22	0.000	Yes
6 (L2Q3)	2 3	48.26	32.68	15.57	8.83	0.003	Yes
7 (L1Q5)	1	80.63	63.98	16.65	12.26	0.000	Yes
11	4	88.16	82.67	5.49	1.73	0.189	No
16	1 2	84.82	84.95	-0.13	0.01	0.913	No
17	1	37.70	43.55	-5.85	1.11	0.293	No
21	4	84.87	87.11	-2.24	0.22	0.640	No
23	3 4	82.69	79.19	3.51	0.51	0.474	No
29	3 4	76.28	61.54	14.74	8.42	0.004	Yes
44	3 4	33.33	21.27	12.07	6.27	0.012	Yes
46	1	64.92	67.74	-2.82	0.22	0.638	No

All of the questions except questions 5, 6, and 7 on the final exam were set by the instructor, not the researcher. Questions 5–7 are identical to the pre and post quiz questions given in Space Race: Question 5 is Level 3 Question 5 (L3Q5), Question 6 is L2Q3, and Question 7 is L1Q5. Some of the students that got the question correct on their post-quiz got the question correct again on the final exam: 80.85% for Question 5, 55.17% for Question 6, and 80.43% for Question 7. These results indicate that not all of the students retained their knowledge after playing Space Race but the majority did. In particular, questions that saw a large delta correct from pre to post-quiz results had a higher retention rate. Comparatively, a question that had no significant change in pre to post-quiz performance had a lower retention rate.

Overall, only 5/12 (42%) of the results from Table V were significant. None of the negative delta correct values were significant results. This, again, suggests that students that played Space Race either performed equally well or even better than the students that did not play Space Race. In one case (Question 5), the performance for the game participants is 41% better than that of the non-participants. For Questions 5–7, it is unclear whether the experimental group performed better than the control group simply because they have previously seen the questions. However, since Space Race does not provide quiz answers, certainty on the correct answer would have to come from the student's own investigation after playing the game.

VII. CONCLUSION

Based on the results of the study, game-based learning can be effectively used to teach basic computer programming concepts to students in higher education. Students can find the game enjoyable and those that play the game can outperform other students that do not play the game on the final course exam. In particular, cooperation within the game world can be used effectively to encourage students to teach one another. Also, in some cases, the knowledge learned in the game can be transferable to a non-gaming context and the knowledge can be retained by some students for at least 8 weeks.

ACKNOWLEDGMENT

This work and research was made possible by all the supportive staff in the Engineering 1 department at McMaster University, as well as the first-year engineering student participants. We also like to thank Michael Viveros who helped us develop Space Race for our study and Kevin Browne, Andrew Curtis, and Dr. Christopher Anand for their advice.

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How Students Use Media: A Comparison Across Faculties

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***Abstract*—The pervasiveness of online information services has led to substantial changes in higher education including changes in faculty members' teaching methods and students' study habits. This article presents the results of a survey about media use for teaching and learning conducted at a large Canadian university and highlights trends in the use of new and traditional media across university Faculties. The results of this study support the assumption that student media usage includes a mixture of traditional and new media.**

Keywords—Media Usage Habits, Educational Technology, Teaching and Learning Survey, Technology-Enhanced Learning;

I. INTRODUCTION

A Media Usage Survey was developed to provide researchers with a detailed understanding of student' technology use in learning and of possible environmental factors that may influence that use. This survey incorporated the entire spectrum of media services, and focused on creating a knowledge base for universities to understand the media usage of students and to establish a longitudinal international survey on technology use in tertiary education.

II. RESEARCH METHODOLOGY

The survey uses an anonymous questionnaire format consisting of 150 items. Specifically, the tool measures usage frequency and user satisfaction with 53 media services, including information services such as Google, library catalogues, printed books, e-books, printed journals, e-journals, Wikipedia, open educational resources, and bibliographic software. In addition, the tool measures communication services, such as Twitter and Facebook; e-learning services, such as learning platforms and wikis; and media hardware such as tablets, desktop computers, smartphones and mobile learning [1]. Partial results of this survey showing students' satisfaction with media is described in [2], and for engineering students only is shown in [3].

The survey tool was first developed in 2009 and used at the Karlsruhe Institute of Technology (KIT). During the course of 15 follow-up surveys that were administered on an international basis, the original survey underwent optimization, translation into several languages, and validation. In this study, the survey was administered at Western University in London, Ontario, with undergraduate students. The survey, which resembles a student questionnaire, intends to compare the media usage of students by examining possible divergences in media culture that may create problems in the use of media for studying and learning.

In the period between January 16th and February 15th 2013, a total of 19, 978 students were invited to respond to the survey. Subsequently, exactly 1,584 visits occurred at the survey website. Among the invited students, 1266 started to answer the questions, 985 completed the survey, and 803 submitted, a completion rate of more than 90%.

Western researchers, in cooperation with research team members at the KIT, conducted the standardized and comparative analysis. Initial invitations to participate in the research and two reminders were sent by email. Both faculty and student surveys were voluntary and anonymous, as indicated in the letter that were distributed. For the student survey, three e-mails were sent by Office of the Registrar staff to a stratified random sample of undergraduate and graduate students enrolled on the main campus in the Winter 2013 academic term. The data for this survey was collected online using Unipark.

Table I. Response numbers for those who answered the question: Which faculty offers your primary area of study?

Which faculty offers your primary area of study?		**Students**	
		Frequency	**Percentage**
Respondents	Science	173	21.9
	Engineering	56	7.1
	Health Science	125	15.8
	Social Science	237	30.0
	Arts&Humanities	82	10.5
	Other	116	14.7
	Sub-Total	789	100.0
	Missing	196	
	Total	985	

III. FINDINGS

Analysis of the survey requires interpretation of additional information concerning the current habits of media use for studying and teaching. In addition, the survey presents several limitations, including the reality that survey results fail to explain facts or observable behavior; rather, the answers merely analyze participants' responses to the questions.

A. General Media, Learning, and Studying Habits

The differentiation between students regarding their faculties shows just a few significant results, and these only between two certain groups (e.g. students from Engineering state that they study in groups more frequently than students from Arts & Humanities and Social Sciences, which might even be surprising). In general, the results indicate that students from all faculties attend class most frequently, followed by studying using a computer, and by themselves at home, as shown if Figure 1. All students use to search the internet for learning materials, and students from Engineering visit libraries less than other students.

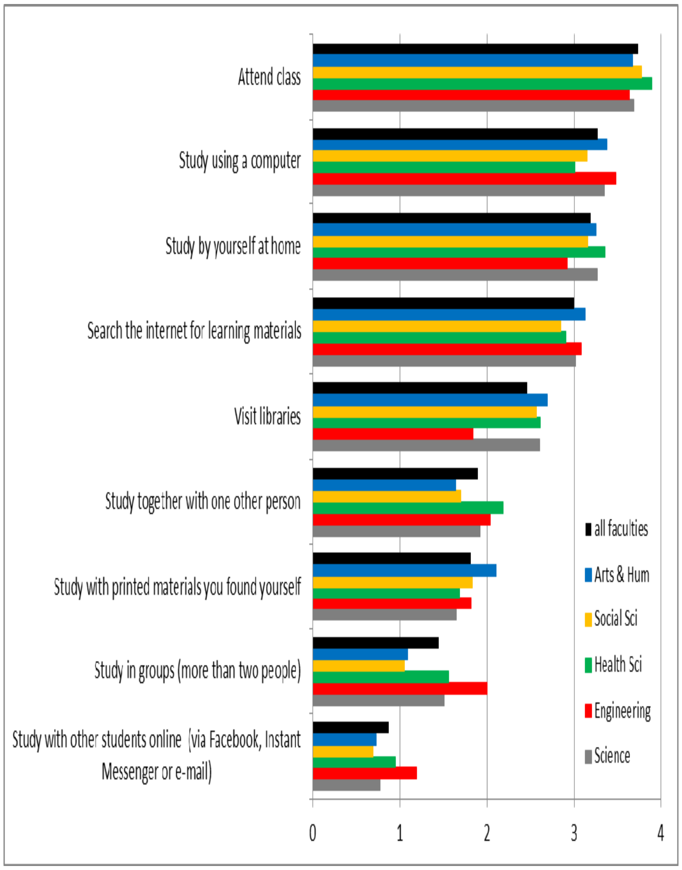

Fig. 1. Means of students' responses to the question: How often do you do the following? The question was rated on a five-point Likert scale with the following choices: "never" (0), "rarely" (1), "sometimes" (2), "often" (3), and "very often" (4); the figure shows the means of all students (valid n = 985) and of 5 subgroups, related to their faculty (Arts and Humanities valid n = 82, Engineering valid n = 56, Health Sciences valid n = 125, Science valid n = 173 and Social Science valid n = 237) (sorted by the means of all faculties).

B. Frequency of IT-Services Usage

The answers from students in different faculties were usually similar in the areas of usage frequency of various IT-devices for learning and studying. The one different is that Desktop-PCs and Computer Labs on Campus are often used by Engineering, as depicted in Figure 2.

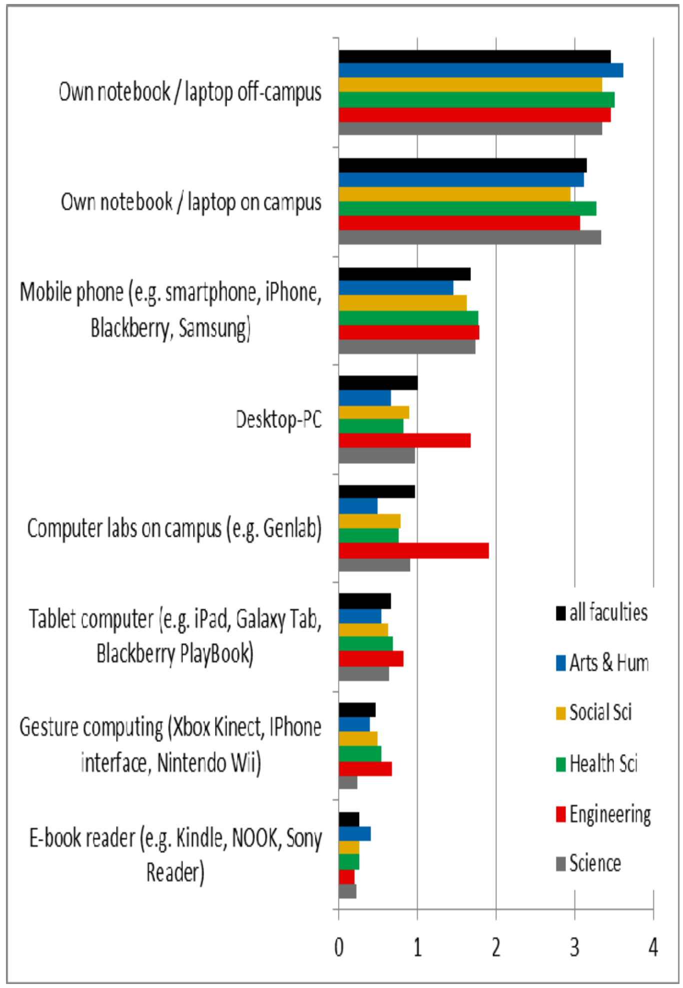

Fig. 2. Means of students' responses to the question: How often do you use the following for learning/studying?

C. Usage of Applications Related to Social Network

The survey results concerning the usage frequency of applications related to the social network is displayed together with the result for Google search, because this seems to be a necessary measure for the relevance of the other items. So, Facebook – the Internet application with a very high frequency in free time usage – is used far less frequently than Google search for study purposes, and Wikipedia seems to be even more relevant up to the present. Significant differences in the use of Wikipedia were evident, with the students from health sciences reporting less frequent use for learning than students from Science and Engineering. Students from Health Sciences stated a slightly higher frequency of usage for the items related to Facebook (compared to students from Arts & Humanities) and Google+ (compared to students from Engineering and from Science). Please refer to Figure 3.

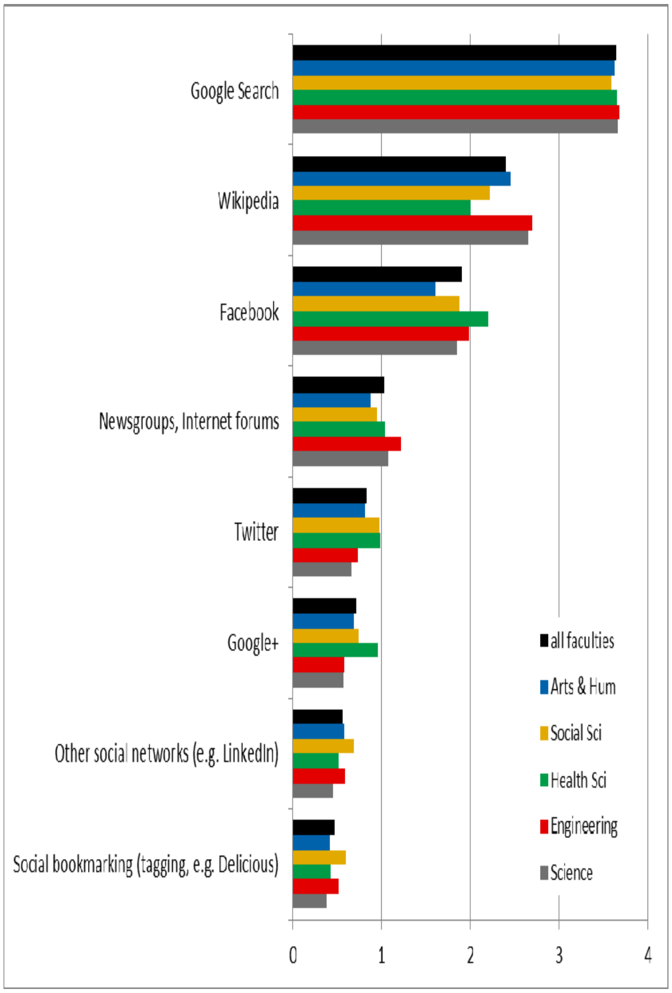

Fig. 3. Means of Students' responses to the question: How often do you use the following for learning/studying?

D. *Frequency of e-Learning Applications*

The usage frequency of diverse e-Learning applications is headed by video sharing websites (but on a notedly lower level than in freetime use), which in general are utilized more than recorded lectures. Significant faculty differences are apparent for the item "online (self) tests for studying", with Arts and Humanities students being less frequent users than students from all of the other three faculties with which they were compared. There also were significant differences on the use of recorded lectures, with Science students reporting more frequent usage than the other students, this may be because that faculty is reported to be very active in this field and offers several services and contents around recorded lectures. This is described in Figure 4.

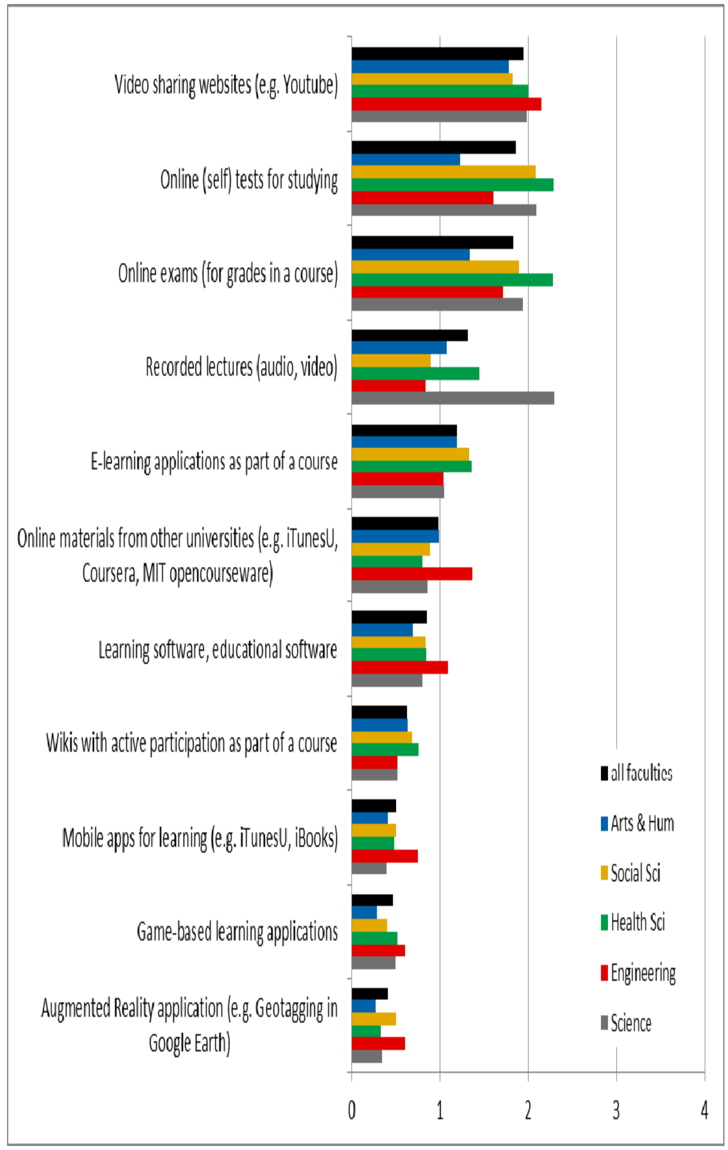

Fig. 4. Means of students' responses to the question: How often do you use the following for learning/studying?

E. *Frequency of Printed Versus Electronic Media Usage*

The usage frequency of printed media compared with electronic media shows similar results for online material and / or scientific articles from instructors. Significant faculty differences were found for the items "online slides (from instructors)" with students from science and health science reporting a higher frequency of usage than students from arts and humanities and social science. Printed books, academic journals, online dictionaries and Google books seem to be more frequently used by students from Arts & Humanties compared to students from some other faculties, and students from Engineering show a higher mean of usage frequency for ebooks. These results are graphically displayed in Figure 5, in the next page.

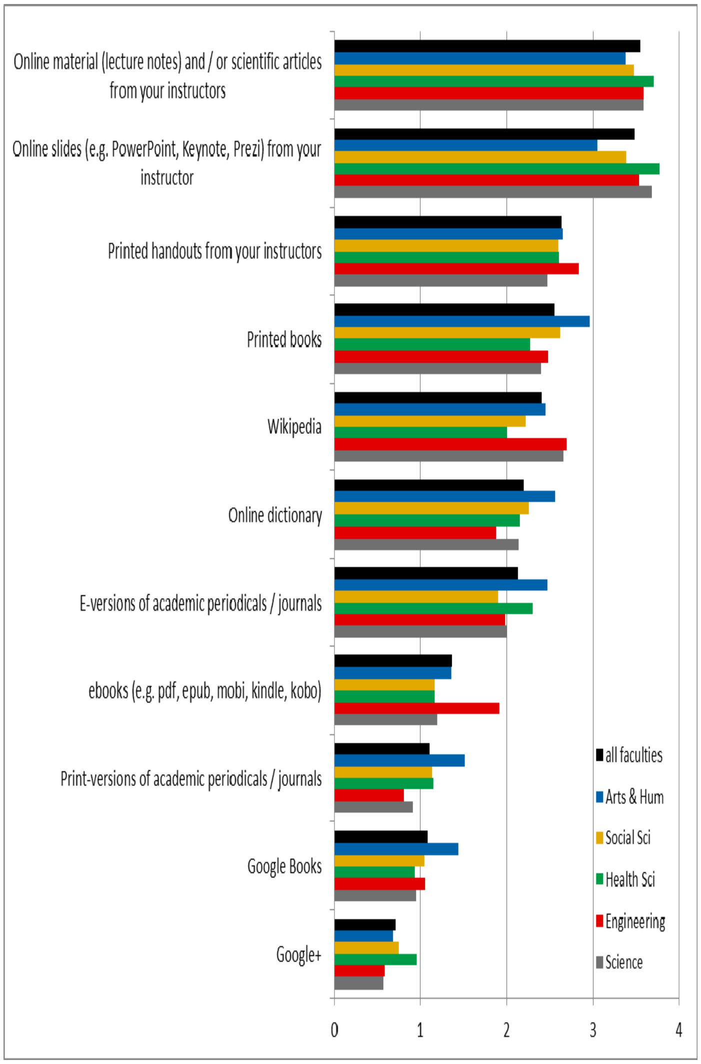

Fig. 5. Means of students' responses to the question: How often do you use the following for learning/studying?

F. *Media Usage in Free Time*

The students were asked about their use of diverse media in their free time. The results generally show an intensive use of Facebook and video-sharing websites (e.g., YouTube), as shown in Figure 6. Reading books and watching TV, two traditional media habits, were used only moderately. Certain media usage, like playing computer games, is, for most students, less relevant. Very new media, such as Google+, seems not to be relevant, at least at the time of the survey. To determine if there were differences between students from different faculties, we compared students from the five largest faculties.

We did find significant differences ($p < .01$) between the faculties on two items: for the item "Read books", Arts and Humanities students reported reading more books than all other students, and for the item "Play computer games", engineering students reported a higher frequency of playing games than health science students.

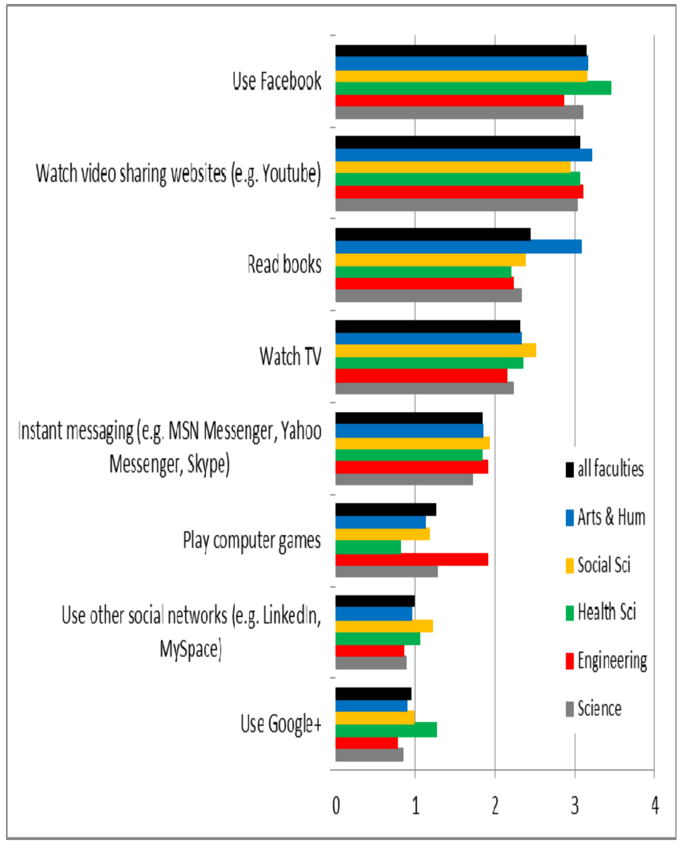

Fig. 6. Means of students' responses to the question: How often do you do the following during your free time?

IV. Conclusion

Looking at the survey results, it can be stated that several traditional media are still very relevant and continuing to be in high use, however, in a changing environment. Printed material and slides from the instructors as well as printed books were deemed to have high values of usage frequency and satisfaction. At the same time, new media, such as the electronic versions of material from instructors, are established and utilized with a similar intensity. It seems that these newly established media, which are based on traditional media, are very easy and comfortable to access and use and, therefore, in the future they are likely to be used more often than their traditional counterparts.

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PSS/E-Based Computer Simulation of Wind Farm Dynamic Performance by Undergraduate Engineering and Technology Students

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***Abstract*—This paper summarizes the teaching and learning of power system transient stability as part of an undergraduate course on renewable energy technologies offered by the School of Engineering Technology at McMaster University. It is based on a term project in which the students were required to design a grid-connected wind farm and then investigate the transient stability of the proposed wind farm using an industry simulation software (PSS/E) offered by Siemens PTI. Essentially the paper provides the perspectives of the instructor and the students on the effectiveness of using PSS/E as a teaching and learning tool.**

Keywords—Wind Energy, Transient Stability Simulations, Wind Turbine Generators, Connection Assessment

I. INTRODUCTION

Key players of Ontario's power industry, including the Ontario Society of Professional Engineers (OSPE), have identified that there is a shortage of power engineers to support the rapidly changing power system infrastructure [1]. The School of Engineering Technology at McMaster University had also recognized this issue and introduced the Energy Engineering Technologies (ENRTECH) program in 2008, under the McMaster-Mohawk Bachelor of Technology Partnership. The ENRTECH program offers a number of undergraduate power and energy courses aiming at the production of skilled power system professionals to serve the provincial and national power industry.

Among all the courses offered, Renewable Energy II (course code 4RT3) introduces wind, solar and hydro power generation technologies to undergraduate ENRTECH students. This course is considered beneficial to students since the province of Ontario in Canada has introduced a feed-in-tariff program to encourage development of renewable energy resources within the province. First offered in the winter of 2012, 4RT3 covers the following topics concerning wind energy:

- Aerodynamics of wind turbines
- Electrical characteristics of wind turbine generators
- Estimation of wind resources
- Cost/benefit analysis using RETScreen software suite [2]
- Integration of wind farms into power grids

When the course was offered for the third time in the winter of 2014, the instructor decided to challenge the students more by requiring them to work on a term project in groups of two or three members. The main purpose of the project was to propose and design a wind farm of at least 50 MW in capacity and then perform a dynamic assessment of the proposed wind farm. Basically, students needed to demonstrate transient stability of their proposed wind farm by using PSS/E.

PSS/E is one of the industry power system simulation software packages widely used by power engineers in North America [2]. McMaster University has purchased an education license for this tool for teaching power system courses. A free version of PSS/E with limited capability, called PSS/E-University, is also available to all university students for educational purposes. Consequently, universities have begun to use it as a teaching and learning tool [3-7].

The purpose of this paper is to summarize the teaching and learning experience concerning wind farm transient stability assessment. Specifically, it provides the perspectives of the instructor and the students on the effectiveness of using PSS/E as a teaching and learning tool.

II. POWER SYSTEM TRANSIENT STABILITY

Before a new wind farm is allowed to connect to a transmission grid, it has to meet a set of stringent connection requirements to ensure that it does not deteriorate the grid reliability. Each grid operator has established its own operating criteria on thermal, voltage, and transient stability constraints, which are covered in Power Distribution I (3PD3) and Power Distribution II (4PD3) at McMaster School of Engineering Technology. In Renewable Energy II (4RT3), the ENRTECH students are expected to apply their power system knowledge to evaluate wind farm transient stability performance.

The concept of power system transient stability is best described by a rolling ball analogy as depicted in Figure 1. Case (a) illustrates that the ball is initially at rest at the bottom of the bowl, representing the power system at steady state equilibrium. At this state all synchronous generators are rotating at the same synchronous speed. When there is a disturbance on the power system, such as the occurrence of a short circuit, one or more generators will start to accelerate. After the short circuit is removed, presumably by protection devices, and if the power system is strong enough, the generators will oscillate for a small period of time and eventually settle at new equilibrium state. This is analogous to the ball rolling up and down inside the bowl and eventually settling at the bottom of the bowl again, as shown in Case (b). The power system is said to be transiently stable in this case for the disturbance under consideration. However, if the system is not strong enough to withstand the disturbance, one or more generators will eventually go out of step and lose synchronism with the rest of the generators, resulting in transient instability. This is analogous to the ball rolling all the way up to the rim of the bowl and escaping from the bowl as shown in Case (c).

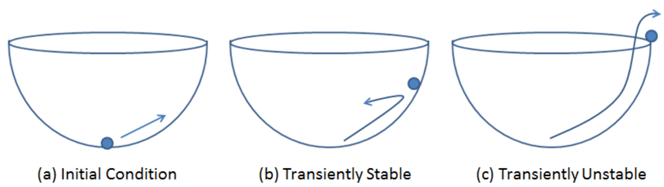

Figure 1: The Rolling Ball Analogy

The trajectory of the power system under transient conditions, analogous to the trajectory of the ball rolling inside the bowl, can be obtained by solving a set of algebraic and differential equations through numerical integration algorithms. If a simulation tool and a simple procedure are provided to the students, they can easily evaluate transient stability of a test system once the modelling data is assembled. ENRTECH students employ PSS/E-University as the simulation tool for evaluating power system transient stability.

III. THE TERM PROJECT

The 4RT3 term project required ENRTECH students to propose and design a wind farm of at least 50 MW in capacity, to be connected to the 230 kV portion of a test system. The modelling data of the test system was provided by the instructor in PSS/E format. The wind farm proposal included the following aspects:

- MW capacity
- Siting (proximity to existing transmission lines)
- Wind turbine generator equipment selected
- Wind farm collector system design
- Dynamic performance evaluation
- Cost/benefit analysis
- Other considerations such as CO_2 reduction

IV. TRANSIENT STABILITY SIMULATIONS

This section presents samples of the dynamic simulations that the ENRTECH students have performed. It will briefly describe the test system, the wind turbine generator model, and the simulation results produced by PSS/E-University.

A. *Test System*

The test system is presented in Figure 2, which contains two conventional synchronous generators and one wind-turbine generator, equivalent of all the wind generators within the proposed wind farm. All generators supply electrical power to an infinite bus via four 230-kV transmission lines. The power from the proposed wind farm is injected into one of these transmission lines as shown. The wind farm collector system is represented by a single equivalent feeder together with two transformers. This modelling approach is a common practice in the power industry [8].

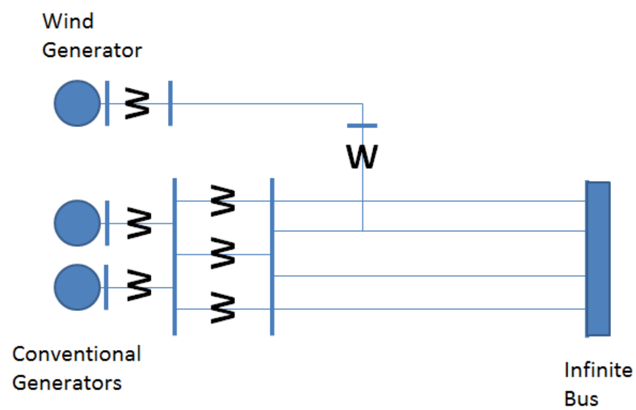

Figure 2: Three-Generator Test System

B. *Selection of Wind Turbine Generator Type*

There are four types of wind turbine generators available on the market, as shown in Table 1. Type 1 and Type 2 are older facilities that still exist on today's power grid. Type 3 and Type 4 are the newer facilities which are likely chosen by today's wind developers. All ENRTECH students selected either Type 3 or Type 4 in their 4RT3 projects. PSS/E-University provides standard models and typical parameters for all four types of wind turbine generators.

Table 1: Types of Wind Turbine Generators

Type 1	Induction generator
Type 2	Induction generator with adjustable rotor resistance
Type 3	Double-fed induction generator
Type 4	Induction generator with full converter system

C. *Simulation Results*

After incorporating the proposed wind farm into the test system, the students simulated the transient stability of the system by applying a short circuit to a transmission line. The short circuit was then removed after 0.1 seconds by disconnecting the short circuited transmission line, after which the system trajectory was simulated up to 10 seconds. The system was declared transiently stable if all generators reached a new steady state after a brief period of oscillations, as illustrated in Figure 3. On the other hand, the system was declared transiently unstable if one or more generators lost synchronism with the rest of the power grid as illustrated in Figure 4, or if the power system experienced a voltage collapse as shown in Figure 5.

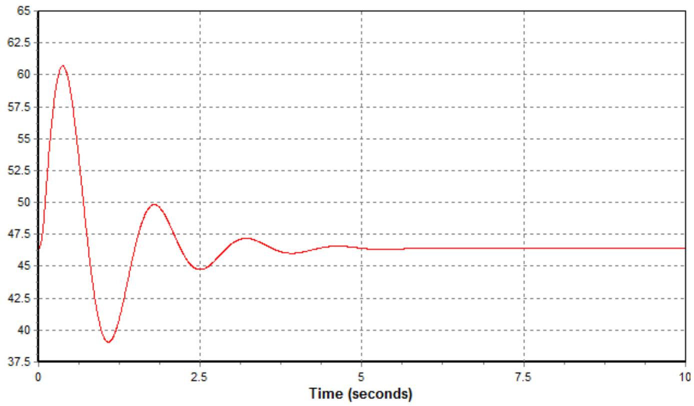

Fig. 3: Rotor Angle (in degrees) vs Time - Transiently Stable

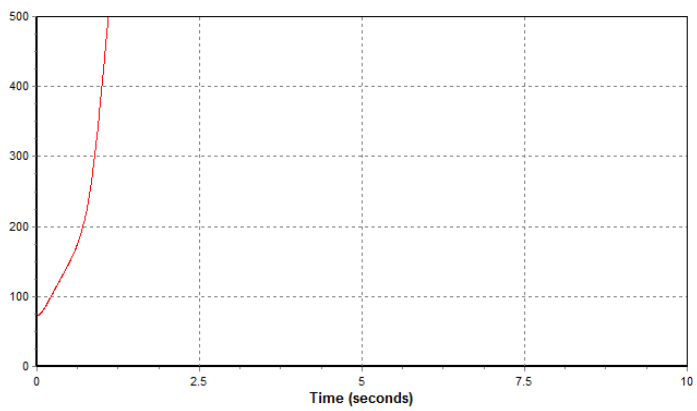

Fig 4: Rotor Angle (in degrees) vs Time: Transiently Unstable

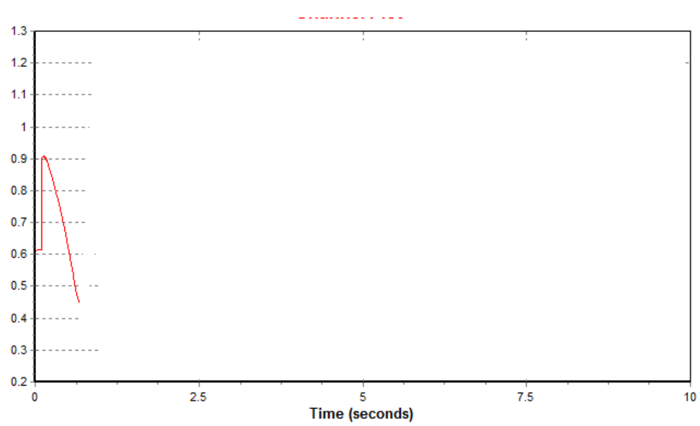

Figure 5: Bus Voltage (in pu) vs Time - Voltage Collapse

V. TEACHING EXPERIENCE OF INSTRUCTOR

When it comes to teaching time domain simulations of power system transient stability at the undergraduate level, a number of points can be made. This section provides a summary of the experience gained by the instructor.

First, it is quite beneficial to teach power system transient stability using realistic multi-machine power systems and detailed generator models. Excellent textbooks [9, 10] on this subject are already available to students. When transient stability is taught as part of an undergraduate power system course, usually only a couple of lectures are devoted to the topic. As a result, the simple Equal Area Criterion (EAC) method is generally covered for power system transient stability analysis. EAC is simple but has no practical application since it is limited to a single generator system with the generator modelled as a constant voltage source behind a transient reactance. This overly simplified generator model cannot accurately simulate the transient stability of wind turbine generators.

In order to teach the transient stability of wind farm, it is necessary to model the wind turbine generators in sufficient detail. This can be easily accomplished with PSS/E-University which comes with a model library for a wide range of power system equipment including different types of wind turbine generators. It is also advantageous to introduce PSS/E to students as early as possible since this power system simulation tool is widely used by power engineers in North America.

Secondly, it is highly desirable for students to have PSS/E-University loaded on their own computers so that they can do their work anytime and anywhere they like, provided the test system does not exceed the dimensions of the free version. The 4RT3 test system was created in such a way that it is just slightly below the maximum size allowed by PSS/E-University. Unfortunately, it implies that only a small number of generators can be accommodated. In preparing the test system, the instructor could only model three detailed generators in the test system. A lot of effort was spent on reducing the original full size system into a small equivalent network.

Thirdly, the test system and its modelling data should be prepared by the instructor and provided to the students as a complete set in PSS/E format. Students should only need to make minimal parameter changes to the test system provided. Typically for a 4-month course, the students would not have enough time to become familiar with many features of the simulation tool. However, if they are provided with a canned run-stream, they can start running transient stability simulations very quickly after receiving a demo from the instructor. The transient stability simulation procedure generally involves the follow steps:

- Prepare a test scenario by adjusting the wind farm output
- Perform a sequence of switching events to simulate a short circuit and its removal
- Analyze the simulation output by plotting key variables such as generator rotor angles and bus voltages

Apart from the demo, the students also need a step-by-step description of the simulation procedure so that they can work on their own when the instructor is not around.

VI. Learning Experience of Students

One of the objectives of the 4RT3 project was to connect a wind farm to the grid and evaluate its transient stability. This required multiple changes to system parameters until the resulting output showed system stability or instability. PSS/E-University allowed the students to accomplish this in a very short period through active experimentation and reflective observation. Once the students had learned the procedure required to run PSS/E, they were free to run multiple scenarios to produce the desired outcome. PSS/E allowed changes to system parameters such as connection location to the grid, wind turbine type, size and fault conditions. Using graphical output analysis features, students were able to determine power system transient stability for any set of system conditions under investigation.

The project was set up with pre-existing models for wind turbine generator type, dynamic data and network configurations. This reduced the amount of time it took to accomplish the project objective and students were focused on learning the cause and effect from changing the test system conditions. A tutorial session was given by the instructor to explain the steps required to run PSS/E dynamic simulation. Many students found it difficult to take notes when they were shown how to navigate through various windows in PSS/E. The lack of experience using PSS/E required a written procedure from the instructor for navigating and executing the simulations. The easy use of PSS/E allowed the students to pick up the process quickly and became proficient in running transient stability simulations.

The team environment allowed each team member to focus on one or two aspects and accomplish the project goal sooner. Having each team member use PSS/E-University allowed them to run independent simulations while evaluating stability for the system conditions they chose to simulate. As a team, they collected the best results from individual simulations and compiled them into the final simulation to evaluate the collective best choice. Students had a higher retention of applied theory using simulation because of the visual learning aspect that came with reviewing graphical data showing cause and effect from varying input data.

The use of PSS/E-University simulation software allows a student to transition from a theoretical state of learning to an experimental state of learning. However, running simulations without any previous knowledge on how to operate PSS/E can be difficult due to the overwhelming functions that can be performed. However, PSS/E does provide an extensive user manual [11], and with the guidance from a teacher with working knowledge of PSS/E, the student will be able to operate the program for what is needed.

Some questions about the test system arose when simulation results were questionable. The lack of understanding of the dynamic models left some doubts about early results from the simulations. The following improvements have been suggested when using PSS/E-University as a learning tool:

- Incorporate more PSS/E assignments and learning objective in earlier classes. These learning elements should focus on the use of the simulation tool.
- Include lessons that incorporate basic features of PSS/E. Possibly include modelling or network development, setup and simulation.
- Include simulations as part of class lectures to improve student engagement and demonstration of the applied theory. Graphical results offer a visual learning component that identifies cause and effect of varying conditions related to the lecture's objective.

VII. Conclusions

Wind farm transient stability simulations were introduced to ENRTECH students through a term project for the first time in the School of Engineering Technology at McMaster University. Although a significant amount of work was required to prepare the test system, the experience was deemed valuable by the students through their course evaluations. Suggestions have been made by students to improve the learning experience next time the renewable energy course is offered.

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Importance of Human Computer Interaction (HCI) in Critical Success Factors (CSFs) of e-Learning

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***Abstract*—Distance learning is not a new concept in education. Hundreds and thousands of people around the world have got degrees and diplomas through this method and there is no second opinion too on its benefits. In this paper it is going to be examined e-learning which is a modern form of distance learning method. A survey has been conducted in different under-graduate and post-graduate classes at the Firat University to find out these Critical Success Factors (CSFs) which act as bearers in student's success. Survey results have shown that Human Computer Interaction (HCI) is one of the most CSFs for e-learning method.**

Keywords—Distance Education, e-Learning, Critical Success Factors (CSFs), Human Computer Interaction (HCI);

I. INTRODUCTION

Distance learning program was first time introduced in late 18th century at Chicago, USA. It was correspondence program, all study material had been sending to students by mail [1]. Invention of radio and later television provided better delivery mechanisms for instruction. While over-all system was still not perfect because it was all one-way communication; students could listen and watch but could not ask any question. Computer and internet have taken place of radio and television in the society and many institutes are also using that medium for their distance learning programs. In this paper it is going to be examined that when computer and internet is providing a better communication facility why still in distance learning or in e-learning, students are not having satisfactory results. A survey was conducted during spring and fall semesters of 2013 academic year in the department of Software Engineering at Firat University. Survey results showed that the biggest bearer in success is students' interaction with e-learning systems. Many students who enroll in these courses don't have any previous experience about e-learning tools or systems and they feel it difficult to use. Second it has been also observed that designers of these systems try to make systems very complex and they forget that user is an average student who is going to start studying after a long break. HCI is actually the study how humans and computers can interact with each other more effectively.

A. Critical Success Factors (CSFs)

Critical Success Factors (CSFs) are the factors which play important role in performance or in success of any department, institution or system [2]. This paper is about e-learning systems so all factors related to e-learning systems will be discussed here. E-learning is based on three things, course material, e-learning system and students as shown in Figure 1. The most important thing which connects all three stakeholders is HCI. In simple words it can be said like this HCI acts like a bridge between three.

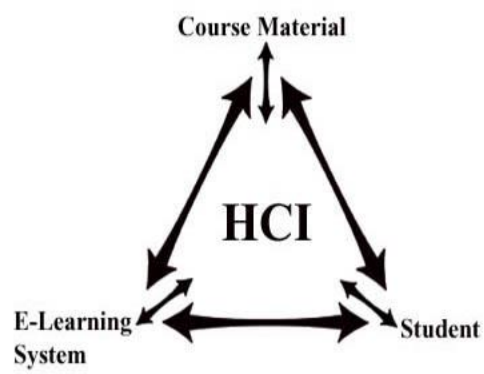

Figure 1. An interactive e-learning model.

B. Human Computer Interaction (HCI)

Designers of e-learning systems mostly focus on course materials or on standards of e-learning systems, but these two things are not enough for students to have success. In traditional face-to-face class room teaching, students can communicate with their teachers. They can ask questions and all things which they don't understand but e-learning is not as simple. In e-learning system computer is not only a course book for students but also a teacher. As much good students will be able to communicate with their computers as much good it will be for their results.

II. SURVEY

In survey 15 questions had been asked from students. These questions were typically about views on their e-learning experiences.

- What are their views on e-learning systems;

- What benefits they can have by choosing e-learning courses;
- What technology they have been using to deliver and access e-learning materials;
- What are their expectations on the learning in virtual environments;
- Best practical examples.

A. Method

For survey emails were sent to all under-graduate and post-graduate students from the chair of the department (Prof. Dr. Asaf VAROL) [3]. In addition survey was also advertised on the homepage of the department website. Total number of students that participated in the survey was 450, 380 under-graduate and 70 post-graduate students during the spring and fall semesters of the 2013 academic year.

B. Key Findings of the Survey

Benefits of e-Learning

In survey, respondents identified two main benefits of e-learning: Figure 2 is about graphical representation of survey results.

- Accessibility and availability of courses and course material.
- Flexibility of time.

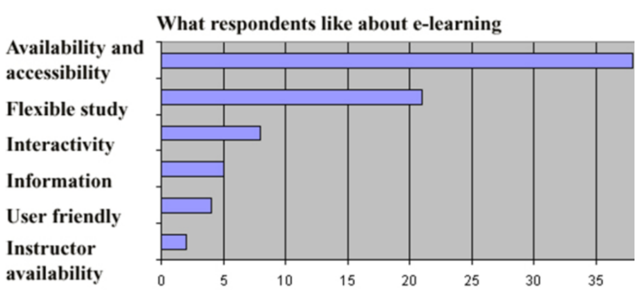

Figure 2. Graphical representation of Survey results.

[Note: Randomly selected 400 respondents and divided into 40 groups of 10 students]

According to 58% of respondents in survey, the biggest benefit of e-learning is availability to access the course material from any location particularly the option to work from home. For 34% of respondents, time when they want to study and how much they want to study is second biggest benefit. Some respondent views:

"**As a mother, it is a lot easier for me to attend a lesson from home and at my own free time**." (Postgraduate Student)

"**As a part-time student, study according to my work schedule is biggest help for me**." (Postgraduate Student)

"**I do live quite far from campus, so travelling to campus for classes and for submission of assignments is not easy and affordable. E-learning is best solution for me in this condition**." (Undergraduate Student)

Drawbacks of e-Learning systems

According to majority of respondents in survey, there are three main drawbacks of e-learning and e-learning systems:

- Lack of communication between student and teacher;
- Technical issues regarding e-learning systems;
- Computer and internet access requirement.

There were mixed responses about the technical issues and requirement to have computer and internet. 14% of respondents said technical issues as a drawback of e-learning. The main issues are following as shown in Figure 3:

- Unavailability of internet and system failures;
- Systems security (especially for assessment purposes);
- Data losses;
- Slow-running systems.

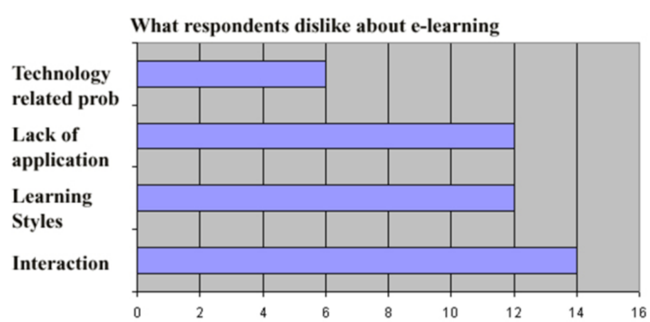

Figure 3. Graphical representation of Survey results.

[Note: Again randomly selected 400 respondents but this time divided into 16 groups of 25 students]

9% of respondents in survey expressed concern about availability of internet access. While 77% of respondents remarked on usability and interaction issues. They had difficulty in finding required course contents from e-learning systems. To overcome this problem there is a need for research in improving the HCI of e-learning systems. As much it will be easy to find required course contents as much it will be helpful for students to have better results. It is therefore concluded that if HCI of e-learning systems can be improved, one further barrier to success will be removed. Some respondent views:

"**Available course material is unnecessarily complicated. Sometime I spend more time in finding than reading**." (Undergraduate Student)

"**Each course module has its own style of page and icons whenever I start a new module first I spend a lot time in learning navigation of the page**." (Undergraduate Student)

"**Even all course contents are available, but still sometime I feel it would be better to have a teacher who could explain where that my required material will be found**." (Undergraduate Student)

III. Human Computer Interaction (HCI) for E-Learning

There are some very important issues in HCI which should be keeping in mind when designing an interface of a learning environment.

- Command Line Languages (CLLIs) and Instructions

The Command Lines Interactions (CLIs) usually have cryptic keywords and strict syntax. They are not easy to use and even missing a single character produces error [4], so it can be said like that CLIs are better for experienced students than new ones.

- Menus Design

The biggest advantage of menus is that they could be recognized easily rather than recalling. Design should be logical and meaningful so required option could be recognized easily. It is evident that menus eliminate number of errors and reduces time for complex tasks.

- Direct Manipulation Tool

Direct Manipulation Interfaces (DMI) is very useful and successful especially in e-learning systems and for new students. They don't require any previous training and are analog to basic human skills. Students feel great control over the displayed contents, windows and slides [5]. Some important points of DMI:

  - Few minutes' demonstration is enough for new students to learn basic functionality;
  - Experienced students can work fast and more easily;
  - Easy to memorize operational concepts;
  - Easy to visualize the direction of activities;
  - Error rates are relatively very low.

- Form fill-in Design

Form filling is oldest and simplest way of interaction between the user and the system. There are two important points in form designs. Form design should not be too sophisticated or form should not be too long.

- WIMP Interface Tool

WIMP stands for windows, icons, menus, and pointers. It is human nature, human learns more easily and more quickly from visualization than any other way [6]. It is an old and true saying "a picture is worth a thousand words". So it can be said that WIMP provides most influential option for interaction in e-learning systems.

A. Theories and Models

Some people argue that HCI is just a tool and it does not need any study or theory. It is not right. Aim is not to develop a system with some course material and some links. Aim is to deliver knowledge, skill and education without complications and without face-to-face interaction [7]. Before going to design an HCI model it is necessary to understand what a student really expects from a virtual class room and what his previous experience is? An effective HCI model cannot be produced without understanding of mental capabilities of students [8]. HCI is actually combination of human psychology and computerization.

B. General principles for HCI Designs

- Define the students' requirement.
- Define the environment in which system will be used.
- How much control students should have over the system?
- Nature of course contents and other material.
- Duration of the course.
- Feedback concept.

IV. Conclusion

This research paper serves as a guide line for institutes and departments who wish to start e-learning programs or going to develop new systems for existing e-learning courses. E-learning is a lot different than tradition class room. Students have only screens in front of them and they are their course books and teachers both at same time. HCI cannot take the place of a teacher but in some ways it can fulfil some communicational gap between the students and system. Survey results shown that majority of students who get enroll in e-learning or distance learning programs they don’t have much experience about internet and computer systems. So it is necessary to think about this issue before designing a system second as it is a general concept that HCI means just a colorful page with a lot of contents. That concept is totally wrong. HCI is a tool which makes easy for user to interact with system. HCI design should not have any complications. As a conclusion it can be said like this e-learning systems are just for delivering course material to students so they should be as simple as possible and not have anything which students need to learn before using them.

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Smartphone as a Learning Platform for Sensors and Measurement Technology

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***Abstract*—The sensor and measurement technology is an undergraduate course for mechanical engineering majored students, which is usually taken in the third year. The course topics include sensor principles, and signal processing theories. In the traditional teaching style, students learn theories in the class, and then do experiments in the laboratory. There is a time interval and lag between theories and experiments. Students can't see what they have learned at once. To solve this problem, a smartphone experiment platform is designed, which can show experiments in the class. For the sensor part of the course, built-in sensors of the smartphone are adopted to do demonstration experiments. For the signal processing part, the virtual instrument method is adopted to show the signal processing result. In the new teaching style, abstract theories are equipped with perceivable smartphone experiments. Students can see, hear, and touch theories on their own smartphones, thus they are more active and engaged in the class.**

Keywords—Sensor, Measurement, Experiment, Smartphone, Teach;

I. INTRODUCTION

The sensors and measurement technology is an undergraduate course for mechanical engineering majored students, which is usually taken in the third year. The course topics include sensor principles, as well as signal processing theories. Before 2011, the course was taught in a traditional way. Students study theories in the class for about twelve weeks. And at this period, they go to the laboratory to do experiments for about four times. There is a time interval and lag between theories and experiments. Students can't see what they have learned at once. This makes formulas and theories hard to learn and to understand; and the class atmosphere is a little boring and monotonous. To solve this problem, a new experiment based teaching style is proposed. When a new theory is taught, the teacher does a demonstration experiment in the class to show how the theory works.

For the class experiment equipment, it must be small and easy to carry. The smartphone is a good choice. It has about ten built-in sensors that can be borrowed to do sensor experiments, such as the vibration monitoring by its acceleration sensor. It has a powerful CPU and a colorful screen that can run virtual instrument programs to explain signal processing theories, such as the energy leakage and fence effect of FFT spectrum.

This work is supported by China government, within the framework of the project the CNC products innovation demonstration, Contract number: 2012BAF13B06.

In the new teaching approach, theories and concepts are designed as perceivable smartphone experiments. Students can touch the sensor in their smartphones, they can hear signals of different frequency, and they can see the spectrum of different signals. The theories and concepts are not so abstract for students. They are more active and engaged in the class. At the same time, students can more easily to build a link of what they have learnt with real world applications.

II. COURSE DESIGN

To help students have a better understanding of the course, we must add a non-mathematical and experiment based approach to show theories and formulas, and use it as a supplement of the class teaching.

A. Structure of the course

To let theories and formulas of the course perceivable, the teaching activities of the course are separated into the theory and experiment two parts. Fig. 1 is the structure of the sensor and measurement technology course. The left is theories, and the right is related experiments. Usually each teaching unit contains one or two experiments. When a new theory or concept is introduced, the teacher let students do one or two experiments on their own smartphones.

Theory	Experiment
Sensor Principles	Sensor Part
Resistance type sensor	Temperature by resistance sensor
Capacitance type sensor	Touch screen by capacitance sensor
Electromagnetic sensors	Vibration by piezoelectric sensor
Piezoelectric sensor	Orientation by magnetic sensors
......	......
Signal Processing Theories	Signal Processing Part
Waveform analysis	Digital signal generator
Spectrum analysis	FFT spectrum analyzer
Correlation analysis	Distance measurement by correlation
Digital filtering analysis	Digital equalizer
......	......

Fig. 1. The structure of sensor and measurement technology course.

B. *Sensor Principle Part*

The sensor principle part introduces various sensors and their working principles. Students need to learn dozens different types of sensor, such as the resistance sensor, the capacitance sensor, the inductive sensors, the piezoelectric sensor and the electromagnetic sensor.

Usually, the working principles of a sensor is not difficult to teach, but it is a little boring if all sensors are only learnt on the paper. For students, working principles of different sensor look similar; it is hard for them to keep attention for a long study time.

We need to bring some changes in the class. Adding sensor experiments to the class is a good ideal. When a sensor principle is introduced, a sensor experiment should be done in the class. For this purpose, teachers need a kind of experiment equipment that is small and is easy to carry. The smartphone is the best choice.

A smartphone is not only a mobile phone. It has powerful computing capability and features, and can be a media player, a digital camera, a recorder, a GPS navigator, or a tiny computer. You may not notice that the smartphone is also a sensor hub, and can be a measure instrument. There are about ten sensors in a smartphone as shown in Fig. 2.

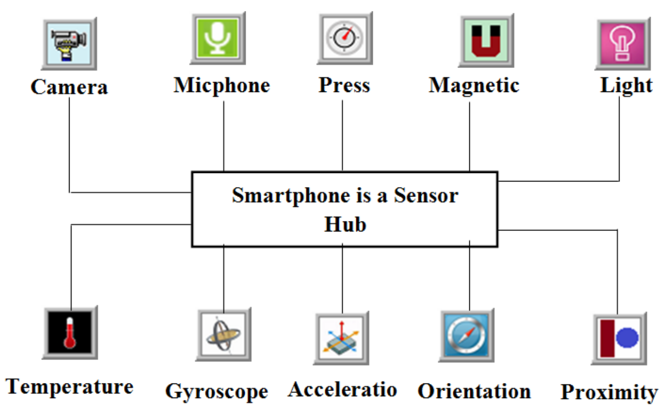

Fig. 2. The built-in sensors of a smart phone.

These sensors include microphone, camera, light, temperature, gyroscope, pressure, accelerometer, orientation, proximity and magnetic field. You can see that the smartphone is an ideal experiment platform for sensor. We can design many sensor experiments on the smartphone. Below is part of sensor experiments that we design for the class.

a) The touch screen position by capacitance sensor
b) The CPU temperature by resistance sensor
c) The vibration measurement by piezoelectric sensor
d) The sound measurement by micphone sensor
e) The Image acquisition by camera sensor
f) The Magnetic measurement by magnetic sensor
g) The light measurement by light sensor
h) The angle measurement by gyroscope sensor
i) The compass by orientation sensor
j) The distance measurement by proximity sensor

Fig. 3 show the result of a vibration experiment, which is realized by the piezoelectric sensor in a smartphone. After the student starts the vibration experiment app, the smartphone begin to record the vibration of the smartphone holder and draw a real time vibration curve on the screen. When a student stand, stretch, walks, jog, or run, the different vibration curves are drawn on the smartphone screen.

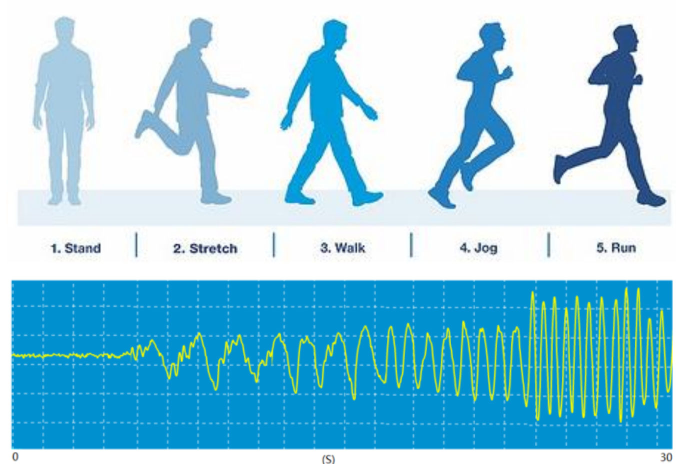

Fig. 3. The vibration experiment of a smartphone.

Fig. 4 show the result of a magnetic experiment, which is realized by the magnetic sensor of smartphone. When the magnetic experiment app is running, it can measure the magnetic field intensity around the smartphone.

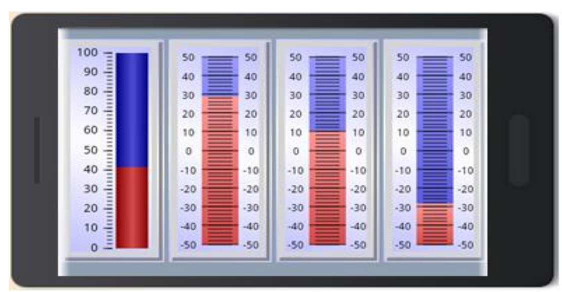

Fig. 4. The magnetic experiment by the smartphone.

By adding sensor experiments to the class, the teaching content can be more vivid. Students can feel and touch the sensor in the class, and they are attracted to query how these sensors work. At the same time, students can also gain some real experiences of sensor application.

C. *Signal Processing Part*

Another part of the course is signal processing theories, which includes the time domain analysis, the frequency domain analysis, the correlation domain analysis, the amplitude domain analysis, and signal filtering. There are many mathematic formulas in this part. It is hard for students to understand signal processing theory if they only study these formulas on the book.

A group of virtual instrument experiments is designed to show signal processing formulas visually. Below is part of experiments that we design for the class.

a) The frequency aliasing and sampling theorem
b) The frequency concept by the sine wave generator and the digital piano
c) The waveform analysis of standard signals
d) The Fourier series concept by the signal synthesis and decomposition
e) The spectrum analysis and the Fourier transform
f) The energy leakage and fence effect of FFT spectrum
g) The auto-correlation analysis and cross-correlation analysis of standard signals
h) The probability density and probability distribution function of standard signals
i) The signal filtering and the digital equalizer
j) The signal modulation and demodulation

For example, when we teach the Fourier transform theory and the FFT based spectrum analysis. Students need to build a concept of frequency, and then they need to know the meaning of Fourier transform. At last, they need to know how a spectrum is figured out by the fast Fourier transform (FFT) algorithm. We design four virtual instrument experiments to visualize the Fourier transform theory, as shown in (1).

$$\begin{cases} x(t) = \int_{-\infty}^{\infty} X(f) e^{j2\pi ft} df \\ X(f) = \int_{-\infty}^{\infty} x(t) e^{-j2\pi ft} dt \end{cases} \tag{1}$$

First, a sine wave generator and digital piano experiment is designed to explain the concept of frequency. Students can see and hear the sine wave of different frequency.

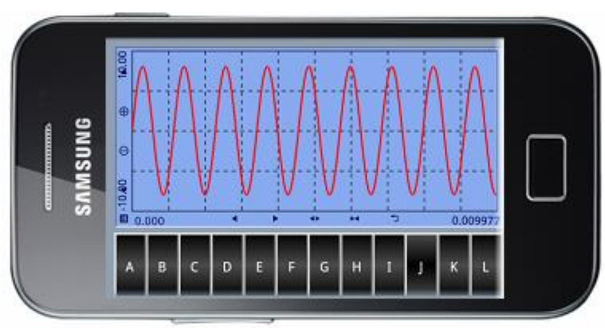

Fig. 5. The sine wave generator and digital piano.

Second, a signal synthesis and decomposition experiment is designed to show the Fourier series. Students can see how a square wave is synthesis by sine waves in its Fourier series.

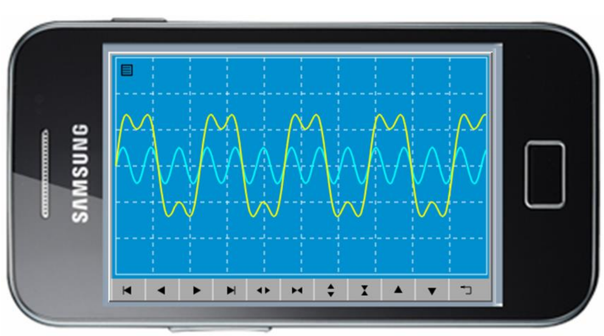

Fig. 6. The signal synthesis and decomposition experiment.

Third, a FFT spectrum experiment is adopt to explain the Fourier transform. Students can see the relationship of Fourier coefficients and the FFT spectrum.

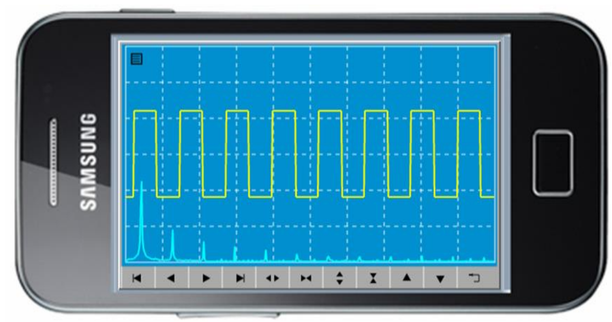

Fig. 7. The FFT spectrum experiment.

Fourth, an energy leakage and fence effect experiment is designed to explain the energy leakage and fence effect in a FFT spectrum and their influence to the spectrum result. As shown in Fig. 8, the left is a 190Hz sine wave; there is no the energy leakage and fence effect in its spectrum. The right is a 192Hz sine wave; there is an energy leakage and fence effect in its spectrum. It can attract students to know why it is.

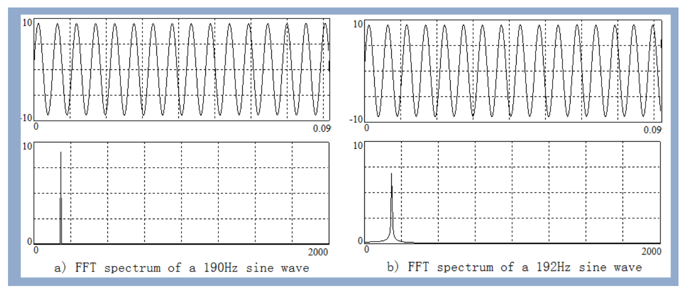

Fig. 8. The energy leakage and fence effect experiment.

Fig. 9 is a FIR filter experiment. The original signal is composed of four sine waves. By changing the pass band of the FIR filter, students can see that some frequency components in the signal are removed from it, and they can understand the real meaning of signal filtering.

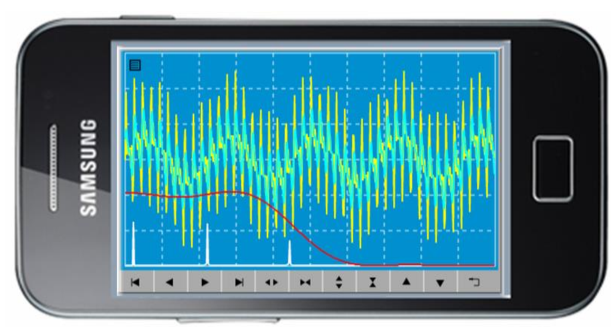

Fig. 9. The FIR filter experiment

By adding virtual instrument experiments to the class, abstract formulas are shown as visual curves and graphs. Students can understand signal processing theories form these experiment more easily.

D. Student Projects

To encourage students to use knowledge that they have learn, a small application projects is left for students to finish after the class. For each project, students need to program a sensor or signal processing related program by Java, JavaScript or MATLAB, and run it on their smartphone or PC.

Fig. 10 is three projects that are suggested to students. The project I is a signal generator. When it is finished, students can hear sounds generating by themselves, and they can even play music on the touch screen of smartphone. The project II is a FFT spectrum analyzer. When it is finished, students can acquire their voice from the smartphone microphone and find frequency components in their voice. The project III is a digital filter and equalizer. When it is finished, students can remove some frequency components from the song or music, and make the song or music listen different.

Project I: Digital Signal Generator

Project II: Spectrum Analyzer

Project III: Digital Equalizer

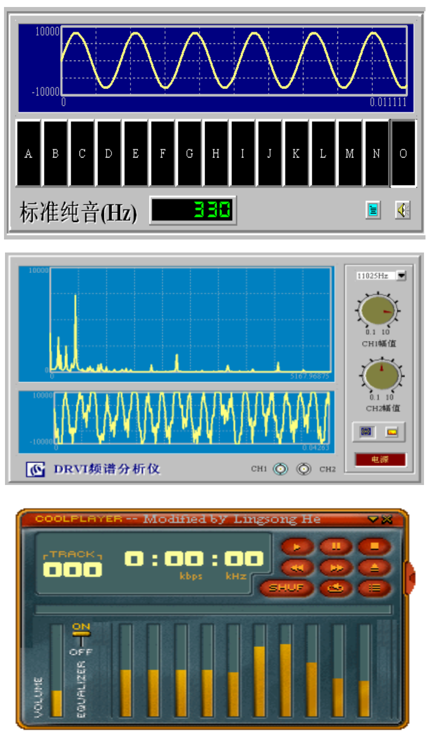

Fig. 10. Three interesting projects in multimedia field.

Students can also suggest a new project to the teacher, but the project must cover some theory points of the course, and the project would not be too hard to finish, or too simple to solve. The new project would also be interesting and easy to get an real application.

III. Application

Fig. 11 is the smartphone experiment platform that is finally designed out by JAVA. It contains about twenty sensors and signal processing experiments. The experiment platform supports the JavaScript language; teachers and students can design new experiments by JavaScript language. After students install the experiment app on their smartphone, they can do experiments in anywhere and in anytime.

From 2011, we try to use the new way to teach the sensor and measurement technology course. When a theory is taught in the class, the teacher let students do related experiments. Students can see theories from a non-mathematical angle, and get a better understanding of the course.

A survey is done at the end of course in 2011, 2012 and 2013. Most of students felt that smartphone experiments were an effective learning tool to help them understanding abstract formulas, and they liked it very much. From 2011, the new teaching mode has been used for three years. As a measure of success, the class has increased from one to three, and students have increased from 24 to 70.

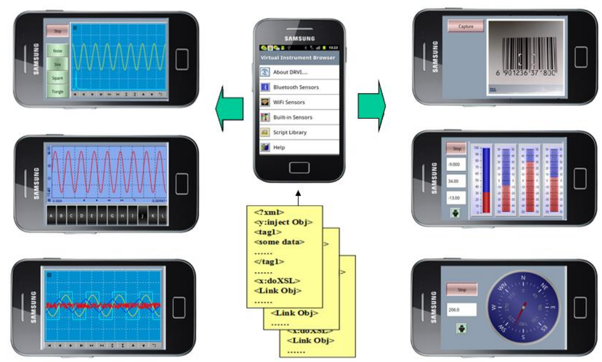

Fig. 11. The smartphone experiment platform.

IV. Conclusion

A smartphone based experiment platform is proposed for the sensor and measure technology course. With the help of about twenty experiments in the platform, abstract sensors and signal processing theories can be seen, heard or touched by students. This greatly reduces the teaching difficulty of the course.

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Enhancing Ethical Awareness though Practical Engagement with Mobile Media

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***Abstract*—Ubiquitous computing technologies play a critical role in the monitoring and assessment of a patient's physical health and medical well-being. They can provide medical practitioners with a way to bridge the gap between intermittent consultations, by providing them with insight into a patient's day-to-day activity and physiological condition. Such applications of technology give rise to many challenging ethical questions, from the end-to-end confidentiality and security of the data collected to the privacy of each individual patient. In this paper we detail a practical laboratory task where final year undergraduate students design, implement and validate a mobile media system to gather data on patient behavior and well-being that can be reported back to a medical practitioner for review prior to a meeting with the patient. We evaluate the students' experience of working with a range of mobile, wireless technologies and devices such as Android smart phones, tablets and wireless sensing platforms. We explore how their perception of the technologies they use evolves and how their engagement with the project enhances their ethical awareness of the use of such technologies.**

Keywords— Engineering Ethics, Mobile Media, Practical Laboratory, Wireless Communications;

I. INTRODUCTION

ABET [1] and other accrediting institutions place responsible, ethical innovation at the heart of the educational and personal development of current and future engineers. The development of these skills, within a formal educational setting, can prove challenging: many students perceive ethics as a rather narrow set of rules and principles that are learnt about, and considered, in isolation; rather than as an integral part of their future professional practice.

The object of the assignment detailed in this paper is to provide students with practical experiences where ethical principles form a key element of the conceptualisation, design and realisation of a real world engineering task. This assignment formed a core element of a final year undergraduate Wireless Communications module.

One of the key aims of the assignment was to bring about a change in students' perspectives of ethics through engagement in developmental tasks that involve a clear, non-negotiable ethical dimension. The sub-tasks within the assignment were specifically chosen so as to encourage the students to engage in collaborative, interdisciplinary ethics research as part of a broader laboratory-based assignment in the ubiquitous computing domain.

II. MOBILE MEDIA AND ETHICS

The emergence and rapidly accelerating growth in the availability of standardized wireless technologies such as Bluetooth, Wifi, and Zigbee has led to research interest in their future deployment in the Internet of Things. This has fuelled the expansion in capabilities of devices such as wireless sensors, smart phones and tablets; together with their associated media technologies. Many of these devices can make intelligent decisions or take action based on the information they have acquired about their surroundings and location e.g. from sensors, accelerometers, GPS. They can also interact on a global scale through social media, such as Twitter and Facebook, apps, email and even common SMS messages.

The ethical issues surrounding "emerging technologies", such as the mobile devices mentioned above, pose many challenges for those involved in their creation, deployment and exploitation [2,3,4]. These issues can range from the way in which they are embedded in everyday life to the protection of the sensitive, personal information they capture and relay. This makes them an ideal tool for the exploration of ethical issues in a practical environment with final year undergraduate students who have already begun to explore the broader impacts of technology on society and the world around them.

III. THE WIRELESS COMMUNICATIONS MODULE

The Wireless Communications module described herein is an optional element of the undergraduate Integrated Computer Science program at Trinity College Dublin. This is a full-time accredited degree program that offers students the opportunity to exit after four years with a Batchelor's degree in Computer Science or after five years with a Master's level qualification, subject to the attainment of an acceptable standard.

The Wireless Communications module runs over a twelve week semester, from September to December, with one laboratory and two timetabled lecture hours per week. The class also have access to any necessary laboratory infrastructure for at least six hours per week. Class size has varied from 18 to 35 students in the seven years that this module has been delivered. Assessment on the Wireless Communications module is carried out through a combination of assigned coursework and a written examination.

Topics covered include the fundamental principles of wireless transmission and how these support and underpin the development of wireless communication networks. This forms the foundation for the subsequent consideration of a wide variety of wireless communication systems from WiFi and cellular networks, through to wireless sensor networks and the apps that run on mobile devices.

Students taking this module have over three years of experience in computer programming, primarily in Java, and have also taken courses in computer hardware, networking and telecommunications. They have also engaged with ethical issues in a number of modules, such as a freshman module on computers and society.

IV. The Assignment

Prior to the commencement of their work on the assignment, students are given a one-hour preliminary class where they are introduced to the assignment's objectives and goals, as well as the philosophical underpinnings of its design. This enables the faculty member to enter into a simple didactic contract with the students, agreeing the anticipated level of commitment, the expectations of both faculty and students and the modalities for engagement with the assignment. In particular, the assessment criteria and anticipated outputs are discussed in detail and agreed upon by all.

The students work in small, mainly self-selected groups of three or four. Each group is encouraged to draw on their pre-existing skillset when deciding on their intended approach to the assignment. A minimal problem domain task specification, such as that used for this assignment, has been found to encourage creativity and novelty in both application area and technical implementation [5,6].

The Wireless Communications module is taken by final year undergraduate students, thus the technical environment in which they work is deliberately chosen to reflect that of an engineer in the real world: The students are provided with a range of wireless technologies with which they can realise their prototype and there is no single, mandated device or platform that they must use.

Those taking the module were given access to the wide range of mobile and wireless devices available for use within the host institution. Where appropriate a rota was established to ensure that each group has access to the necessary equipment. Groups were encouraged to make strategic decisions on the wireless technologies they chose to work with based on their collective skillset, proficiency and interests.

The task description provided to the students was as follows:

A. Background

Medical practitioners often find themselves restricted in terms of the information available to them on a patient's well-being and behaviour. The data they gather is usually obtained through verbal reports from the patient or those who live with them and from journals or diaries kept by the patient. These reports can often be unreliable or skewed in favour of recent symptoms; for example, a patient may concentrate on reporting on the pain they feel today, rather than on the pain they have experienced over the previous week. The ultimate goal of this project is to use mobile technologies to gather data on patient behaviour and well-being that can be reported back to a clinician e.g. a hospital consultant or specialist nurse, for review prior to a meeting with the patient.

B. The Laboratory Assignment

Using the available mobile technologies (Arduino, Wireless sensors and sensor boards, Android smartphones, tablets etc.) design and, where possible, prototype a mobile device suitable for use in the health care setting detailed above.

Behaviours one could consider monitoring include that of adults in an ambulatory setting e.g. in their own home, or multiple individuals in a specialised care facility. One could look to monitor behaviour such as repetitive unfocused behaviours e.g. repetition of the same task, or provide a system to monitor well-being e.g. for fall detection. One could prototype a system to gather information from patients throughout the day; for example, through the completion of surveys on a smart phone or tablet. One could also look to provide a method for aggregating data from multiple mobile devices for analysis and summary in a suitable form for presentation to a clinician.

As the end users of this project are patients you should consider any ethical issues that may arise throughout the life cycle of your project from prototyping to deployment and the gathering of personal medical data.

It may also be appropriate to consider and document any necessary security aspects to the project, even if time limitations mean you are unable to addresses these fully in your final solution.

As well as producing a prototype of your system, you are required to produce a report that includes technical detail on the mobile technology you have used, a discussion of the design philosophy behind your system and the implementation work carried out. Your report should also address any ethical issues that arose during the assignment. The role and workload of each person in the group should be clearly stated in the report. Finally your report should include a one-page description of your system, including the arguments for its adoption, suitable for presentation to a medical professional with a non-technical background.

V. Outcomes

The student groups taking the module in 2013/14 developed a wide range of solutions that spanned the broad scope of the problem scenario. Some of the more innovative student projects are described below to illustrate this, together with the ethical issues that arose during the course of their work.

A. Fall Detection System

The team working on this project looked at existing fall detection systems, noting that the literature indicates that amongst the elderly unattended falls are a major cause of severe injury and even fatalities [7].

The solution proposed was a distributed one involving both decision trees and local thresholds to determine whether an individual has fallen or come close to falling. The system was built using the Arduino (www.arduino.cc) compatible

Xadow (www.xadow.cc) platform. The team connected several coin-sized sensing components using a flexible connector, thus creating a device that is unobtrusive and easily integrated into clothing such as a sweater or t-shirt. The sensors monitored acceleration and reported values exceeding pre-determined thresholds using a Bluetooth Low Energy connection to an Android device. The device then implements a decision tree for each sensor to determine if a fall has occurred and to classify the nature and type of the fall. Where necessary, alerts are then generated for transmission to care givers.

While the prototype was being developed the initial focus was on the security of the data generated and the prevention of malicious attacks e.g. through the generation of false alerts. However, as the team moved into the calibration and testing phase of the work they begun to focus more on the issues associated with the testing of such a system. One of the topics considered was about the ethics surrounding testing of the system and in particular about asking people to simulate falling. The team looked at way of testing their system without the need for a human subject; for example, by placing the t-shirt containing the sensors on a mannequin and then pushing this over to simulate falling forwards, backwards or to one side. The team also explored how they would move beyond laboratory testing to the use of human subjects and the ethical approval they would need to obtain for usability testing.

B. *System for Detecting Activity within the home*

This project attached wireless sensors to doors and used the on-board accelerometer to determine when a door was opened. It was assumed that doors had self-closing mechanisms and therefore individuals needed to open doors in order to move from room to room. The wireless sensors formed a network that was able to monitor an individual's movements about their home. The collected information was time stamped and relayed to a database running on a remote server via a gateway node. This node was equipped with a sensor board that enabled it to make a connection via a cellular network.

Security aspects of the system included the encryption of data for transmission between nodes in the wireless sensor network and across the cellular network. The students also noted issues relating to the security of the data within the data base.

Future plans included the use of an additional sensor to be carried by the person so that their movements could not be confused with those of other family members, care workers etc. Another proposal was the generation of alerts if the individual appeared to remain stationary for too long. The nature of these alerts was considered e.g. an initial alarm that rang in the house to which the person could respond or the generation of an alert to a neighbor, care worker etc.

The team initially focused on ethical issues surrounding the security and integrity of the data collected; they did not envisage the need for ethical approval for the testing of their system as it was "attached to doors, not people". However, as the project evolved issues such as the intrusiveness of monitoring individuals in their own home were considered. The team also developed their sensitivity to the issues surrounding the testing of systems with human volunteers, appreciating that their proposed systems needed to be looked at from a number of ethical vantage points e.g. making sure their wearable sensors were as unobtrusive as possible and that testers were fully briefed on all aspects of the study.

C. *Symptom Logger*

This team of students focussed on tracking an individual's well-being over a number of days or weeks, allowing for the reporting of symptoms e.g. headache, nausea. The system was a mobile application which allowed individuals to log their symptoms as they occurred and also generated alerts to encourage people to log information on their well-being.

It was felt that this system would be suitable for those who experience difficulties remembering information that occurred in the close past i.e. those experiencing difficulties with their recent long-term memory. These individuals may have no difficulties functioning from day-to-day but may not be able to recall what they had for breakfast two days ago or if they were feeling poorly last week. It was also felt that such a system might be suitable for those unwilling to share intimate details in face-to-face consultations with medical practitioners.

The interface was designed to be as uncluttered and simple as possible. The individual was able to record their well-being on a Likert scale [8] and were then encouraged to record their symptoms in a text box. It was noted that the questions asked could be tailored to suit any known medical problems the user was having or to use existing medical questionnaires such as those for the assessment and management of pain.

The system allowed the individual to view the history of the data they had entered, and to make changes to it. However the original information and the amendments made were logged and reported to the clinician. The system allowed the clinician to view information relating to individual patients or to all patients under their care. The application was implemented on the Android platform and it was envisaged that it could be used on either a smart phone or tablet.

The initial ethical issues considered were the loss or theft of the Android device on which the logger was running, along with the secure transmission of the data from the device to the medical practitioner. However, as the project evolved the focus shifted to the recording of data and allowing an individual to edit or delete historic entries. The team engaged in strong debates on whether it was ethical to allow the clinician to view entries that had been deleted by the patient. Concerns were raised about use of the application by family members or care givers rather than by the individual themselves, possibly leading to data that was difficult to interpret. One suggestion was that those involved with the care of the individual could be given their own mobile applications to record their views of the patient's well-being. The team reached the conclusion that they would have to work closely with those with a good knowledge of medical ethics in order to solve these issues.

VI. EVALUATION

Quantitative data was gathered on the students' opinion of the assignment, its impact on their ethical awareness and their familiarity with wireless devices. This is illustrated in Figure 1 below. The survey also assessed the relationships between the assignment objectives, learning outcomes and technical environment. Students were asked to provide qualitative feedback along with the final report on their work.

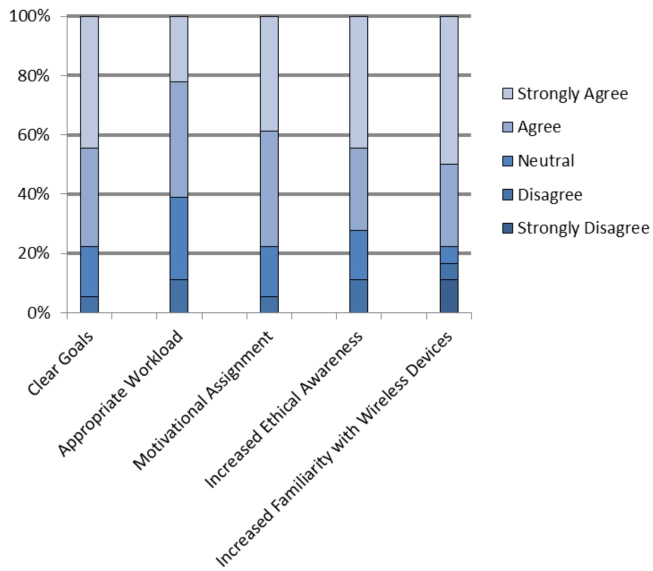

Fig. 1. Summary of Quantitative Evaluation.

A questionnaire relating to the assignment objectives was completed by the students. This showed that 84% of students agreed that 'Creating a novel healthcare application that makes maximal use of the available wireless technologies' was a feature of both the assignment and its assessment criterion. Over 81% of the students also agreed with the statement that the assignment 'Encouraged them to think more deeply about the ethical nature of their work'; while 76% of the students felt that 'Building a working prototype was a key component of the assignment'.

Analysis of the qualitative data confirmed that the students enjoyed working on a real-world problem. They commented that this made the project more meaningful and relevant. They were also very enthusiastic about being given a wide range of wireless technologies with which to work. Some commented that this freedom of choice meant they were truly in charge of the design of their system, in marked contrast to other coursework assignment and projects they had worked on during their undergraduate career. Many mentioned that they experimented with all of technologies available before making their final design choices.

Many students commented on the nature of the ethical challenges they had to consider and how this made them think about ethics in a different light; as one student commented: "Ethics are everywhere".

Some expressed frustration with the operational structure of their groups, for example one student felt that another took control of all of the implementation work and this led to feelings of exclusion. Another common frustration was with the challenges of working with new technologies where not everything works as anticipated or documented; this led some to feel the level of support and guidance given was not as high as they would like it to be.

VII. CONCLUSION

Wireless devices have become ubiquitous and are weaving their way into all aspects of human life and endeavor. They are having an increasing impact on the way individuals live, work, learn and play. The novel laboratory assignment seeks to provide senior undergraduate students with hands-on experience with a wide range of wireless devices, whilst also increasing awareness of the ethical issues surrounding their use in the development of real-world technologies.

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A Comparison of Quality Assurance Systems in Bologna Countries for Engineering Education

A Cyprus and Russia Case Study

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***Abstract*—The paper deals with the quality assurance system in Bologna countries. Our focus is on features of the quality assurance for Engineering education in Cyprus and Russia. The quality assurance system in both countries, Cyprus and Russia, has been adapted according to the Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG). However, the Cyprus and Russia national Quality Assurance agencies are not included yet in the European Quality Assurance Register for Higher Education. The paper reviews the main requirements of ESG. Then it explains in detail and compares the quality assurance systems operating in the two countries, Cyprus and Russia. Finally the paper comments on the methodology applied for the design, the monitoring and the quality control of the two Electrical engineering programs in two universities in Cyprus and Russia.**

***Keywords*—Bologna Process, European Standards and Guidelines, Quality Assurance;**

I. INTRODUCTION

The Bologna Process started in 1999 in purpose to strength the competiveness of the European Higher Education Area (EHEA). Now 47 EU and non-EU countries, including Cyprus and Russia, are members of the Bologna Process [1]. Cyprus is a very small country with a high rate of university graduates although the first universities were established only 25 years ago. Since the independence of Cyprus 55 years ago many young Cypriots pursued university studies abroad and this tradition continues until now. On the contrary Russia is the biggest country in the world with many high ranked universities and a very long tradition in higher education. The Bauman Moscow State Technical University (BMSTU) was founded in 1830. The most of engineering degree holders are graduates of Russian or Soviet Union Universities. Now both Cypriot and Russian Universities offer programs in all three cycles: Bachelor, Master, and PhD.

Quality Assurance (QA) is one of fundamental concern for higher education. The European Network for Quality Assurance in Higher Education (ENQA) is an international organisation which coordinates the QA in the EHEA member states [2].

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In 2005 the Standards and Guidelines for Quality Assurance in the EHEA (ESG) have been prepared by ENQA [3]. The quality assurance agencies that operate according to the ESG are included in the European Quality Assurance Register for Higher Education (EQAR). The current list includes quality assurance agencies from Germany, Spain, Lithuania, France etc.

In the paper our focus is on the QA systems in Cyprus and Russia. Although the two countries belong to the EHEA and the QA system in both countries is designed according to the ESG we may note some notable differences which will be detailed in the next paragraphs. These differences result from the fact that Cyprus and Russia are two very different countries in size, population and industry and have also different history and tradition in higher education. The Cypriot QA system for the time being focuses on the accreditation of private Higher Education Institutions (HEI) and it is now on the way to modify its system and include the public institutions too. The Russian QA system is designed according to national traditions in education. The internal and external, both state and professional quality control provides high quality of education in Russian HEI.

In the paper we give initially an outline of the ESG requirements and then the quality assurance systems operating in the two countries, are described. It is followed by a comparative analysis and a discussion of the two systems. Then the QA systems implemented in two Electrical Engineering programs in two universities in Cyprus and Russia are outlined. Finally, the overall conclusions are formulated.

II. A REVIEW OF QUALITY ASSURANCE IN EHEA

In [4] a QA system is defined as evaluation and accreditation systems together. The QA is one of important issues in Bologna process. First, we will give a short overview of ESG and then we will discuss national QA systems features in the two countries, Cyprus and Russia.

A. General Remarks

The ESG report on QA in Higher Education was prepared by the ENQA in collaboration with three other organizations: the European University Association (EUA), the European

Association of Higher Education Institutions (EURASHE), and the European Students' Union (ESU). This document consists of general policy statements related to quality (Standards) and explanations regarding the implementation of these standards (Guidelines). The three fundamental principles are: a) The interest of students, employers and society in general for good quality in higher education. b) The importance of institutional autonomy which brings with it heavy responsibilities. c) The need for an external quality assurance process specifically designed to ensure the achievement of its objectives.

The ESG are divided in three main Units: a) The ESG for Internal Quality Assurance within Higher Education Institutions, b) The ESG for External Quality Assurance of Higher Education, c) The ESG for External Quality Assurance Agencies.

A key part of this document is the recommendation for the creation of the EQAR which include state and private Quality Assurance Agencies qualified for external quality assurance of higher education institutions. The EQAR has been launched in 2008. In 2009, the third ESG edition has been published with important updates and modifications.

B. The Cyprus QA System

Twenty five years ago there were not universities operating in Cyprus but only some private HEI offering short cycle programs of 1, 2 or sometimes 3 years programs. At the same time the local government had established some state short cycle schools (HEI) which were operating under the responsibility of various ministers related with the field of studies, like the Nursery school under the Ministry of Health, the Police Academy under the Ministry of Justice etc. In 1992, the first state university was founded in Cyprus. Then three private universities and two other state universities were founded as well. The language of instruction in the Private HEI is English and in the State HEI is Greek. The Internal Quality Assurance system in the private short cycle Institutions was very weak initially because there was no appropriate legislation related to quality issues at that time. On the contrary the State and the Private universities which followed implemented an Internal Quality Assurance system in purpose to keep a high level quality of the education offered to students. This it was also due to the competition which was initiated among all the local new universities.

As a result of a new legislation which was established in Cyprus for Tertiary Education, an external QA evaluation process was initiated in 1987. In the framework of this law the Ministry of Education created the Council of Educational Evaluation – Accreditation (CEEA) which is the competent authority for the evaluation and accreditation of the academic programs of the Private short cycle HEI. This council is an independent body has the responsibility only for the private non universities HEI.

The methodology applied for the evaluation of the programs had a similar structure with the one proposed by the British QA system and also by the ESG. The whole process of evaluation consists of the following steps and actions. The private institutions submit applications to the Minister of Education for the educational evaluation –accreditation of their programs. Their applications are then forwarded to the CEEA. The main document submitted to the CEEA is the Self-evaluation report (SER) prepared in English.

The CEEA appoints relevant teams of experts according to the study program to be evaluated. The 5 member team of experts includes by law two experts from foreign universities. The tasks of the teams of experts are the following:

No	External Experts tasks
1	Study the Self-evaluation report (SER) prepared and provided by the institutions
2	Perform on site visits at the institutions whose programs are under evaluation.
3	Prepare a preliminary report addressed to the Permanent Secretary of the Ministry of Education and made known to the institutions.
4	Study any comments that the institutions might provide on the preliminary report.
5	Prepare and submit the final report to the CEEA.

The CEEA Council studies the final report prepared by the team of experts and if deemed necessary, consults the Higher Education Department of the ME and/or the Institution. Finally the council may take one of the following decisions.

No	CEEA Council Decisions
1	Approval of the application and accreditation of the program.
2	Postpone the decision for a defined period of time during which the institutions will try to remedy the specific deficiencies that are identified.
3	Conditional approval of the application and accreditation of the program.
4	Rejection of the application.

The main evaluation criteria are given below.

1. The mission and objectives of the educational Institution, including Learning Outcomes, entrance examination etc.

2. Suitability of the curriculum of the program of study.

3. Faculty and Staff, including qualifications and research results of Academic staff.

4. Infrastructure and resources, buildings, laboratories, equipment, IT facilities, library, sport facilities, etc.

5. Administration and Financial resources.

After the establishment of private universities the local government created a new evaluation body the Evaluation Committee of Private Universities (ECPU) with the responsibility to evaluate and approve the quality of the offered programs. This seven member committee is formed by the council of ministers and includes at least 4 university professors from three different countries. For the quality evaluation methodology undertaken by the ECPU there are two different cases. The first is the case of a new university which applies for an initial license for operation and the second one is the case of a university which has already a normal license and which applies for an educational re-evaluation of its programs for the renewal of its license. This is done every 5 years.

It is given below the quality evaluation steps to be followed for a new university applying for an initial license of operation.

1. Submission of the application for registration in the Universities Registry kept by the minister of education (ME).

2. Study of the application by ECPU which may recommend to the Council of Ministers to accept the application and to register the new university or reject it. At this stage even with a positive answer (registration) the new university cannot enroll students.

3. In the third stage (after registration) the Temporary Board of Governors of the new university after the accomplishment of all required tasks and when the university is ready for operation, submits a progress report wherein all necessary information is provided. After that the ECPU suggest to the Council of Ministers to:

a) Grant an Initial License for operation.

b) Postpone the decision until all quality requirements are satisfied.

c) Not to grant initial license or reject the application.

In case that the initial license for 4 years studies is provided the university can enroll students.

4. This fourth stage is a monitoring of the operation of the new university under the initial license. The ECPU makes periodically evaluations of the university and submits annual reports to the Minister of Education. The evaluations are focused on the educational level of studies, the research work, the infrastructure, the administration and the student's welfare. In case that the expectations of the ECPU are not met the minister may take action for the suspension of the university's operation.

5. At the final stage after the expiration of the initial license for 4 years the ECPU may suggest to the Council of Ministers:

a) To grant a final license.

b) Suspend the initial license and terminate its activities.

c) Extend the initial license for a year maximum and impose to the university to comply with some specific terms.

In the case of private universities with final licenses the QA evaluation of the academic programs takes place every five years. It is based on the ESG and it is very similar with the one described for the private colleges. As regards the State Universities there is no yet an official body for an external QA evaluation. These are accredited by law.

Is there a difference for QA for Engineering Education? In Russia no difference.

Could you add some sentences about professional accreditation in Cyprus?

C. The Russian QA system

Russia has long traditions in education. The first University in Russia was established in 1724. Now many Russian Universities are in the TOP 500 Universities list.

Formerly the external QA model was used in Russian Universities. The Ministry of Education was responsible for QA. However, during recent educational reforms and Bologna process the advanced model according to ESG is exploited [5]. The first state accreditation center in Russia was established in 1995. In 2004, a state QA agency Rosobrnadzor was established. The agency is responsible for evaluation and accreditation of all Russian state and private HEI. In 2005, the mentioned above center was reformed to the federal state institution National Accreditation Agency (NAA, Rosakkredagenstvo). Now the NAA is a branch of the Rosobrnadsor. The NAA is a full member of the ENQA since 2006. The NAA is responsible for the integrated assessment of the HEI including Engineering, Social Science study programmes etc. This is done every five years. In addition to the state accreditation, a University can apply for professional accreditations from professional societies. In our case study an University can apply for accreditation by the Association for Engineering Education of Russia (AEER).

Each Russian University has internal QA system. Its goal is to provide a high educational level during operation. Questionnaires, feedback from students, independent student tests are used in the internal QA process.

Before external QA the SER in Russian is prepared by a HEI. The Rosobrnadzor appoints the relevant team of experts. One team member is appointed as a rapporteur. Experts review the SER and then they visit the corresponding HEI. During on-site visits experts check the curricula, the detailed information about the subjects, lecture schedule and education process according to the Federal State Educational Standards. They visit laboratories and library as well. Experts review curriculum vitae of teaching staff to check the required qualification and scientific achievements of teachers. It should be noted that the requirements for teaching staff for BSc and MSc study programs are different. Final theses are analyzed as well. Experts also review information from social partners, including employers. During the on-site visit experts meet with University and Faculty administration, students, teaching staff. Finally, one expert prepares one evaluation report per one study programme. The report includes information about the study process and student assessment, curriculum design, facilities and learning resources, teaching staff, programme aims and learning outcomes. Finally, conclusions about the study programme are formulated. The report is submitted to the NAA. A rapporteur collects all reports and then prepares a final report about all study programs of the HEI. The final report is signed by all members of the evaluation team. Then the final report is submitted to the NAA.

It should be noted, that 38 Russian Universities including Lomonosov Moscow State University, Saint Peterburg State University, National Research Universities and Federal Universities, including the Immanuel Kant Baltic Federal University (the successor of The University of Koenigsberg Albertina that was established in 1544) can design own curricula. However, they have to correspond to the Federal Standards for Higher Education. Therefore, QA guidelines for the mentioned above Universities are slightly different.

Additionally, in Russia a professional accreditation is possible by professional societies, e. g. the AEER. The AEER is a member of the European Network for Accreditation of Engineering Education (ENAEE) and is authorized to award the EUR-ACE® Label to a HEI.

III. A Comparison of the Cyprus and Russian QA Systems for Engineering Education

The Cyprus and Russian QA systems have many similarities. The external and internal QA system is used in both countries. The state agencies that are responsible for external QA control were established. However, some differences have to be mentioned. The evaluation and accreditation in Russia is more detailed in a comparison with the Cyprus system. In Cyprus different QA agencies are responsible for Colleges and Private Universities. Different methodologies are used for Cyprus Colleges and Universities, while the same methodology is used for all HEI in Russia. We summaries the results of our comparison in Table I.

In [6] the features of QA in Engineering education is discussed. Our focus is on features of QA in Electrical Engineering Education. We outline the methodology applied for the design, the monitoring and the quality control of the two Electrical engineering programs in the two Universities, in Cyprus and Russia. More specifically our focus is on the following issues: (1) The design of the curricular and its approval by an external committee. (2) The formulation of the program according to Bologna directives related to ECTS, employability, recognition and other mobility issues. (3) The introduction of specialized electives in order to satisfy academic and professional recognition requirements. (4) Laboratory equipment provision and installation (5) Industrial Training issues. (6) The proposed monitoring policy for the follow up of the program. (7) Quality Assurance issues related to Internal and External Quality control.

Table I. A Cyprus and Russia Case Study comparison

Item	Cyprus		Russia
	state institutions	private institutions	all institutions
Duration	5 years	Initial 4 years	5 years
		Final 5 years	
Programs	Each program separately	Each program separately	Integrated assessment for all study programmes
Language of the SER	English	English	Russian

IV. Conclusions

The main and important weakness of the current system of QA in Cyprus is that there is no a National QA Agency responsible for the evaluation of all private and state HEI in the same way. It should be mentioned that the state universities are presently excluded from the quality control. In order to eliminate this weakness and improve the overall system in general it is proposed to create new Agency the Cyprus Agency of Quality Assurance and Accreditation in education (CY.A.Q.A.A.E), which will undertake all responsibilities of the existing QA bodies, the CEEA, the EPCU, the Council for the Recognition of Higher Education Qualification of Cyprus KYSATS [7] and the Advisory Committee for Tertiary Education (ACTE). This is a significant step forward. The new QA Agency should include in its board, members from the academic community in Cyprus and abroad, representatives of the Legal Service, Minister of Education, Employer's organization and Students Unions. It should be an independent body and the main responsibilities should be a) the periodical QA evaluation of all HEI in Cyprus and b) the recognition of Higher Education Qualifications awarded in Cyprus and abroad. It is expected that the new system will be much closer to the European practice and the ESG.

In general, the QA state and professional systems in Russia correspond to the ESG. The main weakness of the current state QA system is that all experts are from Russian HEI. However, an international dimension is expected to be enhancing during the coming years. A professional QA system for engineering education in Russia is more international oriented. The representatives from the ENAEE and the Washington Accord signatories have been observers during professional accreditation of engineering education programmes in Russia.

Acknowledgment

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Reforming Mechanical Engineering Higher Education in Africa for Increased Industry Relevance

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***Abstract*—This article investigates the reform needs of mechanical engineering higher education in Africa toward increasing its relevance and responsiveness to the demands of industry and industrialisation in the African continent. It does this by following the Tuning philosophy, which considers input from all stakeholders in curriculum development. Factors such as critical mass of enrolment numbers, quality assurance and accreditation, content relevance, stakeholder linkage infrastructure, and feedback from economic indices, that could provide input into mechanical engineering higher education, are explored. Stakeholder groups are surveyed through a questionnaire to investigate their impressions on the competences desired in graduates. In addition eight country case studies are carried out involving data gathering by each country's representative, complemented by general literature and online sources such as journals, conference proceedings, books, and certain websites. Key findings are that pressure of numbers, stemming from sharp increases in enrolments across Africa are not being matched by quality, rasing questions of graduate employability and relevance of higher education; but continental initiatives are underway to strengthen quality assurance structures in Africa. In terms of modernity, mechanical engineering programmes have been slow in responding to new areas such as mechatronics and nano-systems, and regarding supporting linkages, only a handful of countries have a society dedicated to mechanical engineering, while licensure procedures need more rigour. A strong correlation is found to exist between numbers of mechanical engineers trained yearly and industry's share of GDP. Other economic indices point to the quality of training as needing strengthening to impact industry and increase the industrialisation potential of the continent.**

***Keywords*—Mechanical Engineering, Reform, Quality, Industry;**

I. Introduction

The global competitiveness and economic success of nations have increasingly depended on their capacity to generate, develop, and utilize knowledge for the betterment of their societies. This capacity is strongly linked to engineering higher education, as noted by Abu-Goukh et. al., (2013) [1], who analysed the impact of engineering curriculum reform on economic growth and sustainability, and Markes (2006) [2] and Thom (1998) [3] who focused mainly on industry's perspective and its demands on engineering graduates.

The knowledge economy paradigm of today requires high quality education based on well-defined reference standards. This quality education has become the main gate to human capital development, which is now counted as the most important determinant of national sustainable development. As a consequence, while those already at the cutting edge of the knowledge domain are consolidating their positions, others are striving to catch up through a host of both strategic and ad-hoc approaches. These arguments underscore the rationale for identification and selection of Mechanical Engineering (ME) by Tuning Africa [4] as one of five subject areas whose curriculum reform and enhancement in African universities is essential for the technological and socioeconomic development of Africa. The purpose of this paper is to explore factors such as increased enrolments, quality assurance and accreditation systems, curriculum content relevance, supporting stakeholder linkage infrastructure, and feedback from economic indices, relevant to developing quality ME curricula in Africa for high industrial relevance and impact.

II. Research Programme

A. Aim, Scope and Research Questions

The aim of the research was to explore the reform needs of mechanical engineering higher education for relevance to industry and the industrialization aspirations of Africa.

The objective is to answer the following research questions:

1. How is mechanical engineering higher education (HE) in Africa reforming to make it relevant to the job market?
2. Are current curriculum contents of ME programmes progressive, relevant and responsive enough to Africa's desire to industrialize?

The research is funded through European Union-African Union support.

3. What quality assurance systems are needed in the reform?
4. Are there any trends in enrolment toward a critical mass, and what are the quality and other implications of these?
5. How do correlations between ME and socio-economic development inform HE curriculum reform in Africa?
6. How well do models in the advanced countries fit in developing countries in general, and Africa in particular?

These questions guided the design of stakeholder surveys.

B. *Search and Data Gathering Strategies*

This research is a descriptive, inductive study that generalizes findings based on the study of particular cases.

The curriculum Tuning and Harmonization project aims at identifying and addressing the needs of the productive sector of an economy, mediated by specific social and cultural contexts through engagement of a host of stakeholders [5]. Relevant ME higher education stakeholder groups (employers, academics etc.) were therefore surveyed with regard to the competences desired in ME graduates. The main instrument used for each of eight case studies was a questionnaire, administered by each country's representative in their home country, complemented by literature and online sources including journals, conference proceedings, books, and certain websites.

III. Results, Analysis and Presentation of Findings

Eighteen generic and 19 ME-specific competences, discussed more comprehensively in a companion work [6], were agreed upon as representing characteristics desired in a holder of a Bachelor's degree in Mechanical Engineering. Data from sources listed in section II above, such as numbers of mechanical engineering degrees granted annually in each country, were also assembled, coupled with results from the literature review process, and from the fieldwork and case studies. These were followed by analysis of data to identify trends and patterns, and interpretation of these to elicit inferences and draw conclusions, as presented below.

A. *Towards Critical Mass of Numbers?*

The study reveals that in the past, the number and size of ME Programmes offered in African universities have been small. For example, in Ghana only one university offered ME at the degree level for over 40 years but now, like Zambia and Egypt, there are three, and the number of ME graduates has increased correspondingly. A similar picture can be painted of Ethiopia where great strides are being made in changing the Science and Technology/Social Science enrolment ratio from 30:70 to 70:30, translating directly into increases in the yearly enrolment into ME Programmes (from 800 to 2700 on average) in the near future. In Cameroon general enrolment figures have exceeded existing capacities, now reaching 150 ME engineers/year. Even though Malawi still has only one university offering HE in engineering, there, too, the numbers have spiked. However, in a handful of countries such as Egypt and South Africa, there are relatively high numbers of engineering bachelors per capita which places them not far behind countries like the USA and Germany. Even so, in South Africa there are still plans to boost the numbers of engineering graduates from 8000 to 15000 per year by 2014. In 2009 alone 1459 ME degrees were granted at the BSc level plus 111 at the postgraduate level. The unprecedented expansion signals progress but, at the same time, it has imposed heavy teaching loads and other adverse consequences such as graduate employability challenges and questions of relevance of higher education in Africa [7]. There is a need to restructure ME Programmes and curricula to accommodate these realities. Table I displays data on the numbers of mechanical engineering degrees granted annually in several African countries as in 2012.

Finding 1

There appears to be a confluence of efforts in African universities to boost the number of ME graduates trained each year. However, pressure of numbers presents challenges to quality, employability and relevance of training.

Table I. Mechanical Engineering Degrees Granted Annually

Country & population (pop) in million	**ME degrees granted annually**	**10^4 Capita per 1 ME degree granted annually**	**% of pop. per 1 ME degree granted annually**
Egypt (83)	5500	1.5	0.02 %
Ghana (25)	180	13.9	0.56 %
Zambia (13)	100	13	1.00 %
Malawi (14)	20	70	5.00 %
South Africa (51)	1570	3.2	0.06 %
Cameroon (20)	150	13.3	0.67 %
Ethiopia (91)	800	11.4	0.13 %
DR Congo (71)	NA	NA	NA

Source: Participating representative of each country in the ME group, 2012

B. *Quality Assurance and Accreditation Systems*

Data gathered shows that in Africa, accreditation of ME Programmes is done mostly by a Government regulatory body (as in Ghana, South Africa, and Egypt) but in a few cases it is done by a professional society. Even though more than 60 per cent of quality assurance agencies have been created during the last decade many of them still lack the capacity needed to implement their mandates effectively [8]. In South Africa a new Higher Education Qualifications Framework is being developed. Egypt has also established the National Authority for Quality Assurance and Accreditation for Education, which issued the National Reference Standards for Engineering in 2009. In other countries such as Cameroon quality assurance systems are virtually non-existent in universities.

To address these challenges, the Joint Africa-EU Strategy has explored quality assurance and modernization of African higher education through continental cooperation. The Association of African Universities (AAU) and the African Union Commission are spearheading the quality regimes though the African Quality Assurance Network and the Europe-Africa Quality Connect Pilot Project. The African Union Commission implements the African Quality Rating

Mechanism [9]. The Joint Africa-EU Strategy will take place at three levels: (1) support to institutional quality assurance; (2) support to national and regional quality assurance and accreditation; (3) support to a Pan-African framework for quality assurance, and will promote systematic inclusion of all higher education stakeholders (academics, students, and employers etc.) in quality assurance processes at all levels. The Tuning model, being output driven and addressing competences, skills and the relevance of higher education for employment, has proven to be a valuable way of addressing both quality assurance and harmonisation.

Finding 2

Regional and continental quality assurance structures in Africa are weak, but corrective initiatives are underway.

C. *Content Relevance of Curriculum to Modern Systems*

The study indicates that modern trends are now taking hold in ME curricula in African universities. For example, several countries (South Africa, Ethiopia, Cameroun and Ghana) have introduced in their universities modern programmes such as mechatronics/robotics, advanced manufacturing, micro- and nano-systems engineering, fuel technology, biomechanics, optics, and others. These are in line with efforts to make curriculum relevant to modern systems of design and manufacturing of capital machinery and product systems. Progress in industrialization can only be achieved through a shift from the current primary resource-based economy through beneficiation to a knowledge based economy. Mechanical engineering, being essential to all of industrial activity, does play an important role in this process.

Finding 3

ME programmes in Africa are responding, albeit slowly, to new areas in mechanical engineering such as mechatronics, robotics and automation, and nano-systems.

D. *Role of Stakeholder Linkage Infrastructure in Curriculum Enhancement - Professional Bodies and Licensure*

Results of the country-specific case studies reveal that even though engineering professional bodies exist in Africa, in many cases they are of the umbrella type, such as are found in Ghana and Cameroun. However, in high-population countries such as Nigeria, South Africa, and Egypt there are professional societies dedicated to mechanical engineering. South Africa stands out as having a fairly wide range of discipline-specific professional engineering bodies. Also lacking is one body to network national institutions for synergy. The significance of a Society is that it can provide valuable input to curriculum reform.

Finding 4

There are too few countries in Africa having a dedicated mechanical engineering association, and none in Africa networking national institutions together for synergy.

As regards licensure, the study finds that in Zambia all engineers and engineering firms, are required to be registered with the Engineering Institute of Zambia before they can practice the profession. In Ghana, the Institution of Engineers, though not a Governmental body, is backed by law to register all classes of engineering professionals as well as regulate the practice of engineering. Africa needs a supra-regional organization to set forth the requirements and steps of this process as it is in the USA where an Engineer must pass both the comprehensive *Fundamentals of Engineering* and the *Principles and Practice* or *PE* examinations for licensure. Certification strengthens the ME discipline as a whole, promoting its qualitative growth, from higher education to industry, with consequent impact on industry.

Finding 5

Mechanical engineering licensure procedures in African countries need increased rigour as well as a body for networking national institutions for quality enhancement.

E. *Feedback from Economic Indices*

Table II displays economic indices from a number of African countries. Combining table II with table I and plotting the values results in Figure 1, which reveals that, generally, the greater the number of ME degrees awarded per capita in an African country, the greater is the industry’s share of GDP, the less is agriculture’s share of GDP, and the less agrarian is the workforce of the country etc. Malawi clearly is an outlier, producing too few mechanical engineers in relation to the size of its population. Zambia has the highest poverty rate even though it has a similar average number of people sharing the same mechanical engineer as Ghana, Cameroon, and Ethiopia, and far fewer of them per mechanical engineer than Malawi. This may seem to suggest either an underutilization of Zambia’s mechanical engineers or the existence of quality problems. This connection is seen the clearest in regard to Malawi. Surprisingly, it is Ethiopia that raises the most concern since its industry’s share as a fraction of GDP is lowest among the countries surveyed, even though it has a far higher annual thousand capita per ME degree awarded, comparable to those of Ghana and Zambia.

Table II. Economic indices in a number of African countries

	Economic Indicator (%)			
Country	Industry’s portion of GDP	Agric.’s portion of GDP	Labour force in Agric.	Population below poverty
Egypt	37.4	14.7	32	20
Ghana	27.4	24.6	56	28.5
Zambia	33.5	20	85	64
Malawi	16.9	29.6	90	60
S. Africa	32.1	2.4	9	50
Cameroon	30.9	19.8	70	48
Ethiopia	14.6	46.6	85	29.2
DR Congo	25.9	38.3	N/A	71

Source: [10] & Participating representatives of the ME group

F. *Entrepreneurial Disposition*

Sackey et al. [6], have reported a wide gap between the expectations of ME stakeholders and what is actually offered

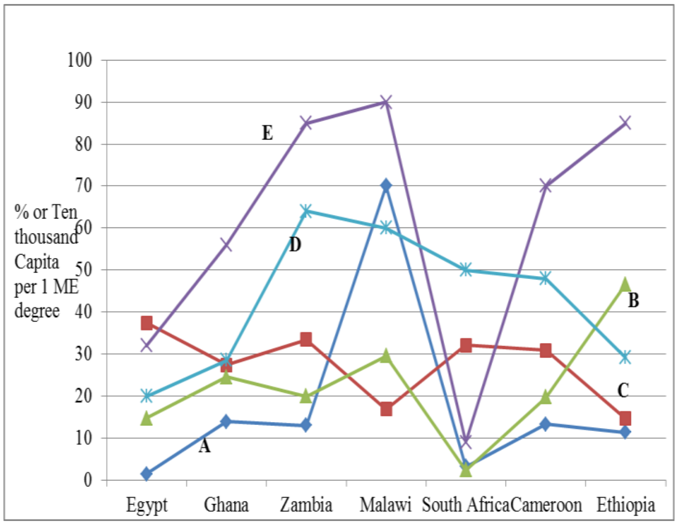

Fig. 1. Correlation between ME degrees awarded annually (A) and percent of industry's portion of GDP (C), population below poverty levels (D), agriculture's portion of GDP (B), and labour force in agriculture(E), in 7 African countries

by higher education institutions regarding entrepreneurial skills. Good practice in training of new engineers should take account of the increasing demands and challenges of globalization by developing managerial and entrepreneurial skills of students, imbuing them with an innovation and new-product thinking mind-set and a potential to adapt to the wider world. This will equip them to employ appropriate technologies to solve problems and pursue independent and life-long learning.

G. Concluding Remarks and Recommendations

The mechanical engineering higher education needs of Africa, unlike those of an industrialized country, must address not only industry relevance of curriculum but also the industrialization aspirations of the continent. While expansion has been the hallmark of the higher education in the last decade, it has also witnessed a host of quality and relevance issues, and weak quality assurance mechanisms confront success of HE in Africa. An international initiative to foster quality and harmonization in higher education in Africa is the Tuning process, which considers stakeholder input in curriculum development. Thus from higher education to industry, ME does play a crucial role in moving Africa from a primary resource-based economy through beneficiation to a knowledge-based economy. Sharp increases in enrolment, while good for increasing engineer to population ratios across Africa, must be matchted by a strengthening of quality assurance structures, licensure procedures, while not fogetting the contributions of dedicated ME professional societies. The results of the study have brought to the fore the need for harmonisation and development of curricula that address the specific technological needs of the continent [11].

By way of recommendations, the main strategic focus of curriculum reform and modernization should be to build the capacity of the African universities to provide quality, world class higher education with increased access to young people on the continent. In these reform efforts, an optimum balance must be found between a focus on higher order thinking skills such as problem solving and industry relevance and a focus on basic engineering skills and subject theory as well as Standards, links with industry and an emphasis on depth and not breadth. There is a criticism that is levelled against Africa for its lack of technical skills, because it has the fewest number of engineers relative to its population size. Development priorities must thus focus on skills acquisition and quality assurance. As Mohamedbhai, G. [12] notes, achieving industrial development in Africa will only come through quality skilled human resources and increased enrolment in Science and Technology programmes of which mechanical engineering higher education is chief.

ACKNOWLEDGMENT

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International collaboration teaching method for Mechatronic Innovation Decision-making and Design Tools

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***Abstract*—In accordance with the Mechatronic Innovative Decision-making and Design, an innovative teaching method is presented in this paper. Both Chinese and foreign professors worked together to teach the basic process of mechanical and electrical innovation. The product design and manufacturing was completed by the students. The course was given in several stages. In the first stage, it was in the form of lectures completed by the cooperation of Chinese and foreign professors; the second phase was carried out in groups: students were distributed into several groups to complete the product design and product manufacturing. Students' final projects were rated by committees. The student's final score was calculated based on the performance of the project report, the completed product, and the product's competition score. An excellent teaching result has been achieved. It not only broadens the students' international vision, but also improves the students' innovation ability.**

Keywords—Mechanical and electrical innovation, Teaching research, Cooperation teaching;

I. INTRODUCTION

Lack of engineering practical experience is a common problem for college students, and it is important to strengthen the practice of design thinking and ability of problem solving[1,2]. Most of the current innovation mode of mechatronic courses have a teacher that gives lectures on a specific topic. Then students refer to materials about the subject, carry on the design, and complete the final design instruction. It is insufficient to improve students' practice ability from this mode because students cannot have a good understanding of the specifications of the product design process.

In order to cultivate the students' design innovation and problem solving ability, this paper presents a new comprehensive practice course: Mechatronic Innovation Decision-making and Design. The purpose of this course is to have students preliminarily form product design basics through the mechatronic product design, to cultivate the students' ability of finding, analyzing and solving problems in practical work, and to improve students' innovative ability, especially the specification design ability of mechatronic products. The teaching method of our university's sino-foreign joint course Mechatronic Innovation Decision-making and Design is discussed in this paper.

II. PREVIEW OF MECHATRONIC INNOVATION COURSES

The contents of existing mechatronic courses for undergraduates are mainly based on the textbooks or written handouts. The contents generally include mechatronic systems, innovative thinking, innovative design tools, functional principles of design methods, etc. Similar to other courses, mechatronic innovative teaching has a teacher that gives lectures and the students follow. The other mode is that a topic is given after the completion of lectures and students are required to finalize the design specification report after reviewing related materials and performing calculations. The two types of teaching modes of mechatronic innovative courses help to foster students' innovation ability in some degree, but still have the following problems:

A. Students cannot consider engineering problems from a global view and do not know how to innovate.

From the existing curriculum, students learned the piecemeal process of innovation; however, they do not know how to start the study of engineering problems and the scientific steps to solve them. They often randomly organize their work progress with their feelings. This is also a common problem in current product design in China, namely, the product design process is not standardized, and frequent rework often happens according to the changing ideas of engineers.

B. Students cannot obtain proper exercise to improve their practical ability, and they are not responsible for turning their designs into a real product.

Most innovative courses are often based on lectures and a small amount of the course requires students to complete a design project. Even if there is design project, students are often required to give two or three dimensional graphics according to a given topic, or to provide only a design specification. This teaching approach ignores the essence of innovation - practice. There is no process to turn the design into a physical product, so students do not need to be responsible for their design. Therefore, innovative design becomes a mere formality, and will not achieve good effects.

C. Students seldom work in teams.

Nowadays, design process is often done by teamwork, a person's ability and efforts are limited. Thus, teamwork is a requirement of innovative design. Using current teaching processes, even if there is a design, students often complete it individually, they seldom work with each other. Students do not understand the importance of team cooperation.

D. It is hard to work internationally. Students do not know how their counterparts carry out innovations and design.

Taking into account of the gap between China and abroad, as the future Chinese product design engineers, students are eager to learn from foreign counterparts about the thinking process and operation procedures of innovation and design. At present, most of the lectures are given by Chinese professors and the ideas are not new enough, so it is difficult to mobilize the enthusiasm of students.

Considering the lack of practical ability of current teaching approaches, this paper proposes the teaching model which is fulfilled by the cooperation of Chinese and foreign professors through the course Mechatronic Decision-making and Design. The innovative thinking and practical ability of students will be cultivated and started from the sophomore year.

III. INTRODUCTION OF SINO-FOREIGN JOINT TEACHING FOR MECHATRONIC INNOVATIVE COURSE

The course is a combination of theoretical and experimental teaching approaches[2], which aims to make students form the basic idea of the innovative design of mechatronic products, to train students with the ability of discovering, analyzing, and solving problem through mechatronic innovative methods and practical innovative process. This course includes two parts, which are theoretical lectures and product design and manufacturing. Theoretical lectures mainly give the basic idea of innovative design and development procedures of mechatronic products. The product design and manufacturing part is in the form of competition. Students are in groups to corporately complete the design and manufacture of mechatronic products. Teachers must introduce students to some basic ideas, principles, techniques and methods of teamwork cooperation and provide proper analysis and guidance for the problems in teamwork.

A. Lectures given by both Chinese and foreigner professors

Famous professors worldwide are invited to give lectures. They teach students the process of problem analysis and product design, and also they will provide students with help during the project process. Domestic teachers participate in assigning design topics, formulating design requirements, and guiding students to complete design and manufacture. Graduate teaching assistance offer help on site. Figure 1 shows a Georgia-Tech professor gives a course lecture.

Fig. 1. Prof. Singhose from GT giving lecture in HUST

B. Courses based open communication and interaction design

The course gives students design tasks, such as designing a robot to complete earthquake rescue. Some tools, devices, funds are provided to students. Students must complete their own design based on lectures, in the meantime, students must manufacture their own products using limited tools, devices, and funds. That is, students need to design product while aiming at manufacturing. Taking into account the real design conditions, designers would use the new technology, the devices provided such as cylinders, ARM boards, which might be beyond the scope of the course, students are required to learn to use these devices based on the materials provided in the course. Figure 2 shows students learning about new design concepts.

Fig. 2. Prof. Singhose and some students from HUST discussing their conceptual design

C. Course score based on participation and attendance

Different from the former scoring methods, which are based on examinations, reports, or drawings, this course is designed to develop students' professional ability of engineering design. Thus, the course refers to the enterprise evaluation methods for product design. The student's final score was calculated based on the performance of the project report, the completed product, the teamwork performance, and the product's competition score, etc. Figure 3 shows two products participating in 2012's competition.

Fig. 3. Competition in 2012

IV. Features of Sino-foreign joint teaching for mechatronic innovative course

A. Cooperative teaching with well-known foreign engineering professors

Through cooperative teaching with well-known foreign engineering college professors, students not only learn about the different design ideas but also learn the knowledge of the design directly from teachers. It is found that students can clearly feel the difference between Chinese and foreign innovation programs through a survey. Students think that the curriculum contents of Chinese professors are exam-oriented and lacks new ideas, while foreign professors tend to focus on the practicability of the lectures, the specification of design process, and the details of the design. From these, the minimum rework could be ensured after design completion.

B. Attentions are focused on the overall engineering design, the pre-planning and thinking of a design, and the cognitive structure of students and the lateral linkages among disciplines.

The course does not focus on a particular aspect of a design, but focus on allowing students to think globally from the engineering design process, which could enable students to develop a standard design habit. This course focuses on the specifications of the design process, including the understanding of customer needs, the researching of product features, the establishment of technical parameters, the design of concepts, the planning of projects, the cooperation of teamwork, and the completion of reports, etc.

During this learning phase, students have completed the basic courses and begin to learn major courses, but they still lack proper awareness of their major. Some of the students do not know what kind of products they will make and will be passive even blind for the major courses, for example, they do not think these courses will help them with the design and thus they will have difficulties in their subsequent study. For this course, the expertise and knowledge as well as their extensions will be simply organized. Students will be told which courses they will learn in the future, what is the extended knowledge of current course, so that students will have interest to complete their future studies.

C. Focus on teamwork and the practicality of the design.

Modern research and engineering projects have a growing need for teamwork. The design and manufacture of products needs teamwork, so it can cultivate awareness and coordination of cooperation of the students. Figure 4 shows students in one group working on their product.

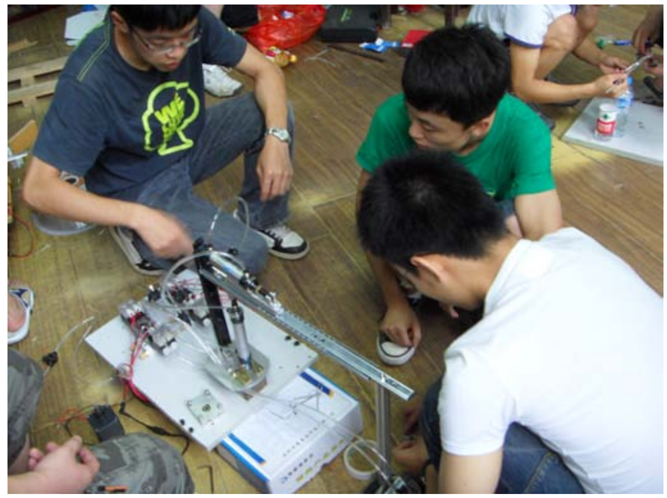

Fig. 4. Students were working on their product

D. Focus on the use of knowledge, the application of knowledge and practice.

This course is designed to focus on students' standardized design ideas. Some of the required design and manufacturing knowledge would be missing, the students who involved in this stage of the program will look up those missed knowledge. Students will complete the design programs based on the information provided or collected. The use of this knowledge will exercise their ability to apply knowledge. Meanwhile, the students complete the design and manufacture of products, learn through their own efforts, and get ability to improve the mechatronic innovation initiatives.

E. New examination scoring mode

The score of the course is a comprehensive process, not only evaluating the students' design products, but pay more attention to students' thinking process, team collaboration between the students, and how they display their products. These are also the qualifications that a good designer should have.

V. Conclusion

Participates in this course were sophomore students. The results from the assessment showed that the students completed the course requirements much better. Students also showed some innovative design capabilities. Students completed the self-study and application of three-dimensional software, pneumatic, and circuit knowledge in a short time, which reflected a good learning ability. Carrying out this innovative model, plus the cultivation of the creative thinking of students, will be very helpful for students in the future.

How to cultivate innovative talents, to mobilize the students' enthusiasm and initiatives, to improve students' comprehensive ability, and to cultivate talents the society needed, is worth more exploration. Education is not fixed, especially higher education in science and engineering. Mechatronic Innovation Decision-making and Design is our initial attempt at mechanical engineering and automation undergraduate teaching. Currently, there still exist problems in student groups and experimental subjects, as well as lack of class and other issues. We hope that in the future we can continuously further enrich the curriculum, improve teaching models and assessment methods, and contribute to the higher education.

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Studies of Energy Use, Green IT Practices and the Role of Entrepreneurship in Higher Engineering Education in Nigeria

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***Abstract*— Africa is a home to diverse sources of natural energy (solar, geothermal, oil and gas, etc.). But it remains an established fact that the continent is still referred to as the Dark Continent due to little or not enough energy generation necessary for economic development and sustained growth. To address the concerns of global rising energy cost there has been global move to implement more efficient Information Technology (IT) resources; this is approached by using IT resources in an effective and economic way. Entrepreneurship and the use of green IT and promotion of awareness thereof through education are employed. Report has it that a reasonable amount of capital can be saved when businesses adopt efficient measures. In order to achieve this, development of a sustainable Green IT plans are required; such as energy conservation, green procurement, recycling, virtualization, governmental regulations, optimization of the IT infrastructures as well as proper awareness strategies are necessary. There is a need for inclusion of entrepreneurship in engineering curriculum and a review of green IT practices across different nations in the continent. This paper focuses on Nigeria and examines approaches to energy use, green IT practices and role of entrepreneurship in promoting innovation and creativity in higher engineering education and research. We investigate the various challenges posed by poor or inefficient IT practices, the role of entrepreneurship in engineering education and practice as well as explore sustainable strategic IT approaches to overcoming Greening Issues, which could have potential impact on economy. A survey of data from diversity of studies show that capitals saved through the various measures could facilitate the implementation of solutions to address some of the existing problems related to green IT issues for improved efficiency and sustainability. Inclusion of entrepreneurship in current engineering education curriculum would prepare the graduate engineers to be employable globally whilst contributing to the nation's economic and sustainable development.**

Keywords—Engineering Studies, Entrepreneurs, Greening Issues, Green IT.

I. INTRODUCTION

Engineering studies and technological research establishes the fact that energy efficiency remains the most cost effective way to reduce energy use. According to *Walter George and Anne Arundel of County Public Schools: "*Anyone who does not have an energy efficiency program is being fiscally irresponsible". To actualize this objective; procurement of green IT infrastructures, recycling of used materials, virtualization, optimization of the IT infrastructures as well as proper organizational policies are necessary. With all these put together; entrepreneurs can achieve high rates of efficiency with minimal risk and a large potential payback. Unfortunately, few entrepreneurs in Nigeria have started these implementation.

Being the fastest growing segment responsible for high energy consumption; Information Technology (IT) industry are looking for strategies to offset rising costs and to use technology in ways that reduce their environmental impact; a term known as Greening Issues. To address this, the need for green IT practices have been attracting attention and interest amongst IT infrastructure manufacturers, suppliers and service providers. Green IT is used here to describe the study and practice of using computing resources in ways that help reduce energy and operating costs, enable sustainable business practices and reduce the environmental impact of IT practices in the larger community [1].

This paper presents the issues emanating from current IT infrastructures and resources usage as related to entrepreneurs in Nigeria, and establishes a dialogue of solutions on how to optimize performance and move forward in a balanced and efficient way that preserves the society through green IT practice. We also present our recommendations as evidenced by reports and a survey of data from diversity of studies for suggested solutions and recommendations for adoption.

II. ENERGY USE AND GREENING ISSUES

High consumption rate of energy by electrical and electronic equipments is one of the major source of greening issues around the world today; due to the rapid uptake of information technology around the world. An average client Personal Computer infrastructure of a 5,000 desktop enterprise, assuming PCs and LCD monitors left in idle state, consumes power at a rate equivalent to the emission of over 4.65 million lbs of CO_2 per year. Average business desktop consumes 717.44 kWh at 1.297 lbs CO_2 per kWh emitted as a result of electricity generation multiplied by 5,000 PCs. A survey carried out by Forrester research indicated that only 13% of organizations surveyed had an enterprise-wide power management program, while another 18% had begun implementing a program but it was not intended for all PCs [2].

Most IT Infrastructure equipments used by entrepreneurs and firms in Nigeria appear to be ‘power-hungry’. The infrastructures found in most data centers include chillers, power supplies, storage devices, switches, pumps, fans, and network equipment. In some cases, these equipments are already at the end of their useful lives, and as such become inefficient. Such data centers typically use 2 or 3 times the amount of power overall as used for the IT equipment, mostly for cooling [3]. Hence, there is a need to explore and investigate the extent to which maintenance engineering could be of use.

Most countries in Africa including Nigeria [4] have neither a well-established e-waste management system for re-cycling of obsolete electrical and electronics product. Available research suggests that the volume of used electronics is large and growing. In a report by GAO [5], some data suggest that over 100 million computers, monitors, and televisions become obsolete each year and that this amount is growing. These obsolete products in most cases are probably stored while they have the potential to be recycled or re-used. These e-wastes contain valuable resources such as copper, gold, and aluminum that are lost if ultimately abandoned or disposed in landfills.

A cumulative effect of these practices does not only result in economic shortfall but also in environmental pollution of the society as a whole.

III ENTREPRENEURSHIP, ENERGY EFFICIENCY AND GREEN IT PRACTICE

To overcome Greening Issues by any entrepreneur, appropriate green initiatives have to be in place, effectual in the design of organizational policies. We explore the concept of energy conservation**,** green procurement, recycling, virtualization and optimization of the IT infrastructures as initiatives towards the practice of Green IT. Touching on the issue of procurement, making environmentally sound purchase decisions by organizations is a major step towards solving greening issues. This is better achieved through the procurement of EPEAT (Electronic Product Environmental Assessment Tool) registered products. EPEAT is a system which helps purchasers in the public and private sectors evaluate, compare and select desktop computers, notebooks and monitors based on their environmental attributes. In Nigeria, EPEAT also provides a clear and consistent set of performance criteria for the design of products, and provides an opportunity for manufacturers to secure market recognition for efforts to reduce the environmental impact of its products [6].

A. Energy Conservation and Virtualization

Implementation of energy management strategies and technologies has the potential to greatly reduce energy consumption. Desktop power management is a critical parameter of any Green IT computing strategy that can be adopted by an organization. The Advanced Configuration and Power Interface (ACPI) specification is an important component of PC power management, which is used to define power management and monitoring.

Use of computers for the control of equipment has been observed to contribute to reduction of costs in terms of managing and running resources in industries. Operating Systems such as Windows 7 leverage ACPI controls as well as additional advanced hardware power management functionality to reduce overall power consumption. A research report released by Mindteck’s Advanced Smart Energy Laboratory indicated that the use of Windows 7 operating system can help organizations save on energy costs. The result shows that cost savings of up to $40.44 (84.46% reduction an equivalence of 6,800 in Nigerian currency) per client per year, not including LCD consumption, can be realized by ensuring that desktop PCs or laptops automatically enter sleep states during working hours [7].

Virtualization is the efficient use of computing resources for collaboration that reduces travel time and cost, increases organizational efficiency, and addresses environmental concerns. In a virtualized system two or more logical computer systems runs on one set of hardware. Through the practice of virtualization; organizations lowers power and cooling consumption, by reducing the number of machines and servers it needs.

Cloud computing, Intranet mailing system such as Lotus Notes, E-Learning, teleconferencing and video conferencing virtualization technologies can be explored to minimize the travel costs personnel spend to attend meetings. On the other hand, technologies such as that of the mobile, IP, web and video-based can be adopted as substitutes. The use of web enabled voice and video conferencing using meeting-ware products to provide presentation sharing and discussion capability are additional Green IT strategies for organizations to cut down expenditures.

B. Recycling and IT Infrastructure Optimization

Recycling of waste materials goes a long way in saving the society economic shortfalls. Facts gathered by Tree Hugger reported that: 44,000 trees will be saved if every household in the United States replaced just one roll of virgin fibre paper towels (70 sheets) with 100 percent recycled ones. One ton of scrap from discarded computers contains more gold than can be produced from 17 tons of gold ore. 9 cubic yards of landfill space can be saved by recycling one ton of cardboard [8]. Organizations policies should be devised on how e-wastes should be managed. There are many manufacturers recycling programs that could be adopted such as HP's Planet Partners recycling service [9]. Although Nigeria being a developing country is considered still backward in putting in place adequate e-waste management schemes, the services of some few available ones can still be explored. A case study is the "Maintenance System Consultants; commissioned by the Lagos State Environmental Protection Agency on Thursday, 21st January, 2010 [10]. The objective was aimed at joining the concerted efforts of the Lagos State Government, private businesses and environmental advocates by establishing in Lagos State a recycling plant for e-wastes. This project opened up a channel for the segregation of e-wastes from the general wastes stream and brought these potentially hazardous wastes into controlled disposal and recycling.

Significant cost savings are realized by ensuring that all PC hardware and software components are optimized. Green IT practice involves a number of strategies to optimize the efficiency of data center operations in order to lower costs and to lessen the impact of computing on the environment. One obvious strategy for data centers operational on obsolete equipments is to invest in new ones that are designed to be energy efficient.

Worthy of consideration is the efficiency of algorithms used for any given computing function operational on computing resources. Although the impact is minimal compared with other approaches, it is still an important consideration. Algorithms can be used to route data-to-data centres where electricity is less expensive. Researchers from MIT, Carnegie Mellon University, and Akamai have tested an energy allocation algorithm that successfully routes traffic to the location with the cheapest energy costs. The researchers project up to a 40 percent savings on energy costs if their proposed algorithm were to be deployed [1].

III. DATA ANALYSIS OF SURVEYS, RESULTS AND DISCUSSION

The present study involved the gathering of data from engineering practitioners, firms and entrepreneurs in the sectors. Survey questionnaires were administered and interviews conducted. Some of the participating organizations included computer and IT Training Institutes and Technology based Businesses. Aptech Computer Education and NIIT Nigeria are the two notable entrepreneurs of IT education in Nigeria indentified for this purpose. The report is as shown in Table 1.

Table 1: Survey Questions Used in to Gather Data from IT Training Institutes

Survey Questions	Aptech Computer Education	NIIT Nigeria
Average total number of computers	400	1200
Total number of centres	14	24
Number of daily hourly use	8	10
Weekly working days	7	7
Total staff capacity	210	480
Staff numbers sent on training to India yearly	6	20
Common type of computers used	Pentium IV	Pentium IV
Computers replaced per annum	20	45

In our study, the following were details utilized to elucidate relevant information in relation to the configuration of the computers used: The cost of one unit (KWh) of electricity, C_ε, cost is ₦11.94 [11]. Intel Pentium IV with the minimum peripheral devices has an energy consumption value, $E_{pc,}$ of 260Watt; 19 inches flat screen monitor has an energy consumption value, E_m, of 36Watt; Power consumption by each set of computer, $P_{pc,}$ is 296Watt on average; Each organization operates 7days per week with a total of 28days in a month; Quantity of Gold in Pentium IV CPU, M_{au}, is 0.05g [12]. 1g of gold bar costs ₦6591.44 [13]; It is assumed that the cost of IT infrastructures used for the Green IT practices is seen as part of capital investment. These figures used in the computation were those available at the time of this research.

The cost of electricity for each firm is calculated using the expression:

$$C_{\varepsilon\,(annual)} = (P_{pc} x1000) x\, C_\varepsilon\, x\, N_{pc}\, x\, T_w\, x\, D_w\, x\, M_y \qquad (4.1)$$

where N_{pc} is the total number of computers in the firm, T_w is Apteh number of hours worked in a day (8.5 hours), D_w is the number of days worked in a week (7 days), M_y is the number of months worked in a year (12 months) and all the other symbols have their usual meaning.

Estimates of the cost for staff training which constitutes continuing professional development, whereby staff were sent to India for a week were calculated for each of the two firms studied, which comprised Aptech Computer Education Institute (A) and NIIT Computer Centre (B). Expenses incurred for stationeries used traditionally for communications such as sending memos and letters were computed and compared to expenses incurred utilizing video conferencing and the use of inter-office communication purpose. The results are shown on Tables 2 (traditional expenses without use of IT) and Table 3 (expenses with green IT practices employed). On Table 4 are the estimated saved cost by each of the firms showing the amount saved as a result of introducing green IT practices in the process and activities of the firms including virtualization.

Table 2: Estimate of Costs of Resources under traditional mode of operation.

Company (firm)	Electricity Cost $C_{\varepsilon\,(annual)}$ (₦)	Staff training cost in India for a week (₦)	Cost of stationeries for communication (₦)
A	4,037,515.78	2,210,952.00	960,000.00
B	14,250,055.68	₦7,369,840.00	2,880,000.00

Table 3: Estimate of Costs of Resources under digital mode of operation incorporating Green IT practice

Firm	With ACPI enabled Electricity Cost $C_{e\ (annual)}$ (₦)	Staff training cost in India for a week through video conferencing and virtualization per annum (₦)	Cost of inter-office communication with Intranet virtualization per annum (₦)
A	3,087,512.06	2,210,952.00	960,000.00
B	11,400,044.554	7,369,840.00	2,880,000.00

Table 4: Amount Saved by Each Firm

Firm	Amount saved through Energy Conservation with ACPI enabled (₦)	Amount saved through virtualisation : video conferencing (₦)	Amount Saved through Virtualiza tion: Intranet mailing system (₦)	Worth of Gold recoverabl e through Recycled of scrapped Computer s (₦)	Total (₦)
A	950,003.71	2,210,952.00	960,000.0 0	6,591.44	4,127,547.15
B	2,850,011.13	7,369,840.00	2,880,000 .00	14,830.74	13,114,681.87

The analysed data above shows clearly that there is huge saving from implementing green IT practice in firms. From the interviews, it was also clear that firms would want to adopt the green IT approach to conduct of business. However there are few obstacles that contribute to them not being able to do. Some of these obstacles include intermittent power supply and in some cases no power at all which makes them resolve to the use of generators. The lack of adequate means of record keeping and available information to help business sector engage in planning and understanding market operations guided by statutory policies constitute a major hurdle to jump over too. As an emerging economy now ranked number one in Africa, it is important to have a solid structure to assist in consolidating most of the systems for marketing and business. Entrepreneurship should be embedded in all levels of higher education to create the awareness of opportunities and allow the students irrespective of their subjects disciplines begin to engage with creativity and innovation before leaving the tertiary level of education.

The findings of our study points to the fact that both firms have earned considerable savings on cost through Green IT practices, which they can reinvest into their respective businesses. Going green and reducing the carbon footprint minimizes high-energy consumption. This has the potential to facilitate increased awareness for all, greater market activities, profit maximization for entrepreneurs, which could benefit everyone globally.

IV. CONCLUSION

We believe the issues raised and covered in this paper is applicable not only in Nigeria but also in some other developing countries in Africa and around the world. It is important that the level of interaction between the public, private and voluntary sectors be well supported and level of accountability be established. Entrepreneurship should be embedded in the curriculum of diverse disciplines in higher education including science, engineering and technology. Executives of firms as well as managements in higher engineering education institutes should seek to enforce these policies and incorporate it into academic curriculum as a form of training for the future generation of leaders of the sectors. We conclude that green skills are increasingly vital for economy and development of society. The insights presented help to shed light on the emerging trends in green computing and the need to have a commonly agreed approach to the development of policies, utilization and implementation of computing resources to make for an efficient and cost effective way. There should be cooperation and joined up approaches developed by the sectors (statutory, business and voluntary) relating to greening issues embedded in engineering education and research, which should link demand and practice with legislation to create conditions for development, progress and sustainability.

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Technical Education: Past, Present, and Future

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Abstract—**University Education in Japan used to focus solely on providing students with specific knowledge or the way to obtain it. Educators did not pay enough attention to applications to real, local, and world problems. However, dramatic social and economic changes due to globalization demand different approaches.**

The purpose of this study is to examine the pros and cons of traditional education [1] and the advantage of the new approaches. The traditional way requires a relatively short time to transfer a large amount of knowledge, but it lacks exercises to teach students to use the knowledge to solve real-life problems. With this knowledge-based method, it is difficult for students to find out what is really necessary for their future. The infamous university entrance exam system enhances this problem.

The emerging approaches presented below include discussions on current environmental problems, ethical questions, and practices and projects to improve student response. 1. Communication skills: Written and Spoken, 2. English as a foreign language for engineers, 3. Other foreign languages, 4. Understanding different values

With these, students are more aware of real problems and become competent in practical skills. Also, they are more aware of other cultures and able to work with people with diverse backgrounds. Diversity is one of the most important areas that need to be addressed. Another area to be discussed is how to assess the approach to learning presented here. While assessment is an area unto itself, we will discuss it as it relates to this subject.

Though Japanese students have many inherent historical, social, and cultural problems to overcome, they have acquired methodologies to do this to some extent. In addition, they can continue teaching themselves to be more efficient and valuable members of society since they know how to get their jobs done.

Keywords—Engineering Education, Communication Competency, Foreign Language, Intercultural Understanding.

I. Introduction

The educational system in Japan has been a center of debate for decades. There are urgent needs for change as our college graduates do not seem to fit in the global labor and business markets. The criticism includes lack of communication skills, flexibility, leadership, creativity, and so on. However, when one looks at the education these graduates have received, it might be difficult to blame them.

II. Pros and Cons of Traditional Education in Japan

In many Japanese schools, from grade schools to universities, classrooms are often arranged as one large table in front for a teacher and many small tables and chairs lined up squarely for students. In there, the teacher talks and students listen and take notes. There are few interactions such as questions and answers, comments, exchange of opinions among students, or between a teacher and students. While students may be active in grade school, as they proceed to higher education, they will become much more quiet and receptive. The pro of this system is that it can enable large amounts of knowledge to be transferred from teachers to students in a short time. Teachers have an easier time explaining one subject and can go on to the next without spending time on responding to questions. Japanese college entrance examination require students to memorize many facts and methods to solve questions so that it encourages their receptive attitude. Moreover, the examination needs to have correct answers, thus enhances students to seek one, and only one answer to a question. This deprives students of thinking, questioning, and creating. When they come to universities, they believe in almost everything in textbooks, reports, and things on the internet. Report (term paper) writing would be a compilation of fragments of facts from other reports, and there are very little analysis on the writers' own. Below is the summary of the pros and cons. They are like two sides of a mirror. Table 1 is the summary.

Table 1. Pros and cons of Japanese educational system

System	Pros	Cons
Lecture style	Quiet, easier management knowledge transfer in short time Receptive Fixed contents, predictable	Lack of interaction =lack of communication skills Lack of own thinking, questioning, analyzing Lack of initiating Monotonous, losing students' interests Less individual creativity
Entrance exams	Answering many questions in short	Tendency to seek only answers

	time	Lack of creativity
Report writing	Compiling facts	Lack of questioning and analyzing

III. New Approach and Its advantage

A. Communication Skills: Written and Spoken

There is a well-known proverb "silence is gold" that indicates that eloquence is not admirable. In classes in Japan, emphasis on written language over spoken is common. Students are trained to improve writing (or rather, answering questions in writing), but significantly less time is spent for speaking. Moreover, English classrooms in Japan have had a tendency to have students "learn English" which means learning the grammatical rules, vocabulary, phonetics, collocation, and so on but not how to use it to communicate. By the end of their compulsory English classes, students know a lot about the language but are unable to express themselves and their ideas in English. The Test of English for International Communication (TOEIC) score for Japanese speakers is one of the lowest among Asian counties in 1997-98 and the situation has not changed very much. [2] The phenomenon has come to the point that Rolf Heeb, president of AIMS International - a headhunting company in Germany - , commented that Japanese workers would not be able to compete with Indian or Chinese workers simply because Japanese cannot handle English well. [3] Hoping to improve such situation, the authors have implemented courses that have students give presentations on their interests in English. Through this activity, the students are required to think logically, introduce the topic clearly with reasonably comprehensible English, both in writing and speaking. Each presenter will receive peer evaluation and suggestions on their clarity and performance after the presentation. By requiring careful teaching plans before asking students to prepare their presentations, the course has been receiving very positive evaluations by the students. They are more confident in dealing with English communication after the course. Table 2 shows the flow of the course from week 1 to week15.

Table 2. Course contents, timeline, and aims.

Week	Contents	Aims
1	Course introduction	Introducing the course
2	English phonetics	Pronunciation practice for communication
3	Individual pronunciation check	Finding problematic pronunciation, correct it
4	Grammar, vocabulary, etc. activities, quiz	Reviewing knowledge of the language, practicing using it in various situations
5	ditto	ditto
6	Short presentation	experiencing presentation, realizing what is needed
7	Grammar, vocabulary, etc. activities, quiz	Reviewing knowledge of the language, practicing using it in various situations
8	ditto	ditto
9	ditto	ditto
10	Written exam, presentation script writing 1: structure	Checking grammar, vocabulary, etc., Learning the structure of presentation
11	Script writing 2	Using knowledge to communicate in writing and speaking
12	Script writing 3, rehearsal	Practicing oral and visual communication and body language
13	Presentation, feedback	Learning to communicate through presentation
14	ditto (different students)	ditto
15	ditto (different students), reflection	ditto, reflecting what was well-done and what can be improved

Week 1 to week 9 mainly focuses on reviewing what the students know about English grammar, vocabulary, collocations, etc. (Most of the students in Japan are required to finish 6 years of English education before coming to universities) Week 2 and 3 are devoted to the sound of the language, in particular. At week 10, the students can review their knowledge of the language through a written exam. With this checking process, they can proceed to write scripts for their presentations in English fairly well. Week 12 has time to rehearse the presentations, but many students have to be pushed to do so for they think "knowing is doing", and to finish writing scripts is the goal. Teachers have to convince them that practicing oral presentation and body language are of utmost importance, and they are evaluated based on these skills. This is the first experience for almost all students to present something entirely in English. Thus, it poses an extremely difficult challenge but is also a reward. Students' evaluations include: "I enjoyed using English for the first time," "I didn't think I could give a presentation in English, but I did," and "I hope to continue studying English."

B. English as a Foreign Language for Engineers

Students who have chosen to learn engineering often express that they hate liberal arts subjects including English. Quite unfortunately, English is always the most hated subject for many engineering students in Japan. One of the reasons is that they feel they have already failed. Even after at least 6 years of compulsory English education, they do not feel they can do something with the language. They cannot understand what was said in English. They cannot express in English what they would like to express. They have memorized many English words and yet, they cannot use them properly to be understood. The sound of English feels quite strange to many Japanese speakers' ears. Practicing English pronunciation makes them embarrassed. However, a large amount of scientific and technical information comes in English. To establish a career as an engineer, one has to be able to read and understand the information, and moreover, to be able to exchange ideas and to interact with people in English.

To motivate the students, we have developed a course to help them acquire necessary skills for scientific paper writing and presentations. A native engineering professor was invited to conduct the course with a Japanese language professor. The former was in charge of the contents and the latter, the language part. It was the first time for most of the students to be exposed to scientific English and the basic terminology for the professor was not necessarily easy for the students. Some such examples are shown in Table 3. The language professor interviewed the students each time to find the problems and difficulties, discussed these with the engineering professor, to help him prepare additional teaching materials to make the course easier for the students. All the students finished presentations and some presented their papers at an engineering conference. They evaluated the course as very helpful and rewarding and gave suggestions that the course should be offered every year and that it should be a final part of the students' English curriculum.

Table 3. Examples of basic terminology that the students had problems with [4].

Kind	Difficult terms in meaning	Difficult terms in pronunciation (listening and speaking)
terms	calibration cogeneration combine conservation consistent entropy friction static	adiabatic flow enthalpy equation equipment instrument isentropic flow properties Rayleigh line

C. *Other Foreign Languages*

In the increasingly globalized world, communicating in English may not be enough. Learning to use other foreign languages should be encouraged. Some suggestions for Japanese speakers are Chinese and Korean languages. The former has 1.3 billion speakers and presents enormous business opportunities. The written form of Chinese uses Chinese characters that Japanese speakers are familiar with. Thus, learning the language has some advantages for Japanese speakers, at least in reading and writing.

On the other hand, the latter bears some similarity in its structure with Japanese and makes it easier than European languages for Japanese speakers to learn. Current popularity in dramas and music from Korea has promoted the language learning. Because of the geographical closeness and business relationship, competence in Korean can be very helpful for students. In addition, success in learning Korean can prompt students to try learning other languages or re-learning English.

The authors have created a popular Chinese language course that combines engineering contents and the language. It is a project-based course, and the students have freedom to choose any theme but are required to give presentations in Chinese. The language professor's role in the course is a facilitator and not a teacher. She minimizes her instruction and suggests that some classmates help other classmates. This collaborative learning usually works very well, particularly with students with lower language proficiency. They are more relaxed to learn from their classmates than the teacher and achieve more. In addition, their themes are diverse and the terms and skills required to present are different from one another. Thus, the students have to find out what they need and to teach themselves. Through this activity, they become more responsible for their learning and become autonomous learners.

Fig. 1. Group of students working together on a project.

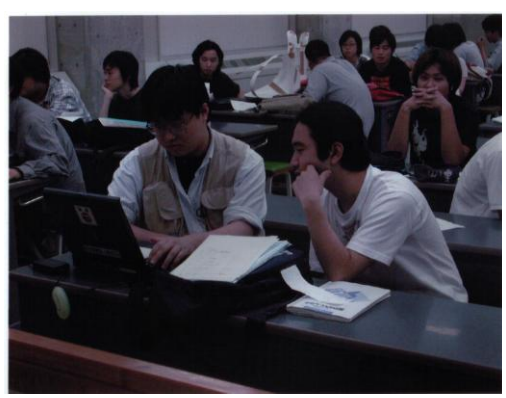

Figure 2. A student is helping another student.

D. Understanding Different Values

The authors have had an opportunity to offer engineering students a course that specifically discussed cultures and their core values. As we mentioned before, many students had reluctant attitudes toward liberal arts courses. However, they are also required to have understanding of liberal arts subjects, such as sociology, economics, religious studies, and cultures, in order to become effective international engineers. Through this culture course, they are exposed to various cultural facts and information and learn to find out and to understand different values from their own. The course first introduces representative cultural information from USA, Central and South American countries, China, Taiwan, Russia, India, and central Asia. The students will then try to analyze cultural symbolism, rituals, and core values. After these exercises, they will choose their themes to analyze and to compare with things in Japan. Themes include various environmental problems (global warming, sinking island nations, endangered species, vanishing rain forest, sustainable development, etc.), ethical issues (genetic engineering, altered bodies, excessive medical intervention, poverty and exploitation, etc.), among cultural themes. They show the students' diverse interests and awareness of current social problems. With time constraints, their analysis may fall into rather shallow ones, the course gives the students a change to think outside of engineering subjects with multiple view points.

Fig. 3 is a sample PowerPoint slide of the students' theme.

Figure 3. Theme: Tuvalu and its future (losing its land to rising sea level, global warming).

IV. Assessment

The courses discussed involve projects and presentations. They are difficult to evaluate objectively. However, the primary aim of these courses is to expose Japanese engineering students to different learning styles from just sitting and listening, and to help them become more responsible for their own learning. With this in mind, assessment should focus on the students' creativity, initiative and leadership on learning, and understanding of different values, rather than mastery of subjects and facts. The students' self-evaluation and peer-feedback are also good criteria to include the assessment to some extent. Teachers should be flexible to experiment by applying various assessment methods. One of our grade criteria we employed was: quizzes (checking if they are following the course) 10%, written exam (checking how much they learned from textbook, lecture, and discussion) 30%, participation and contribution on preparing project (by monitoring each student / group) 10%, and final project presentation (including the students' own evaluation and peer feedback) 50%. Passing line is 60%, so that one criterion cannot pass them in the course. Though this may not be the best way, it has resulted in reasonable grade distribution and students' satisfaction. A majority of the students who finished the courses gave us very positive course evaluation and expressed that the courses opened their eyes.

V. Discussions and Suggestions

There are many professor and teachers in Japan trying to develop various new teaching methods. One may be amazed that students do not change their passive attitudes for learning easily, however. We have to realize that they have adopted the attitudes from their kindergarten and grade schools and continue to carry them to colleges. Something that takes a long time requires a long time to change. At the same time, they are learned behaviors. Young people are not born with them. Thus, teachers need to:

1 be very patient

2 repeat the training through not just one course but various courses (so that there are more possibilities for the students to acquire necessary skills and attitudes)

3 be attentive to students' progress and regress (so that the course can fit to their needs)

4 work together (if possible, between different subjects – enhancing students' awareness for the importance of these skills and attitudes)

We, as teaching professionals, should share the importance of this issue and knowledge we have gained through our attempts to remedy the problems. It has been pointed out for several years that our youths lack motivation to tackle personal and social problems. However, through the courses we have discussed, we have seen the students start responding and working, and they have shown to be very creative. What we need to do is to develop various ways to inspire them.

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A Remote Access Laboratory for Fluids Education in Mechanical Engineering

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Abstract*— The purpose of this research was to develop a teaching module specifically for distance education that would strengthen student understanding of flow through a venturi. An experiment with web based control of and data acquisition from a model venturi nozzle was developed and implemented into junior level engineering classes. The intended use was for distance education by both instructors and students at satellite campuses. Instructors of lecture courses can use the experiment to bring demonstrations of real devices and active learning assignments into classrooms remote from laboratory facilities. The method employed in the research depended on the integration of the remote venturi nozzle experiment into two classes and assessment of learning outcomes via Pre and Post Testing and student survey. The web-based venturi nozzle experiment was implemented first in a junior level fluid mechanics course, as an active learning exercise concerning Bernoulli's equation. In this class the instructor ran the web-based experiment. A pre assessment quiz was given to students after a lecture on Bernoulli's equation but before running the online experiment. A post assessment quiz followed the active learning session with the remote lab. The experiment was then used in a junior level laboratory course, in which a small group of students ran the web-based experiment themselves. A survey was used to assess the outcome of the experiment by the pilot group. Two major conclusions can be drawn from the implementation of the web-based lab. First, the pre and post test indicated that students showed significant improvement in conceptual understanding after exposure to the web-based lab in the junior fluid mechanics course. Second, the student survey indicated that only minor operational changes were needed for students to successfully operate the web-based lab.

Keywords—Remote laboratory, Venturi, Fluid Mechanics;

I. Introduction

The Mechanical Engineering program at Washington State University (WSU) has grown substantially in the last five years. Class size has increased markedly at the home campus in Pullman, and in addition, two new satellite campuses at Bremerton and Everett are the home to placebound students who receive instruction from onsite instructors and from Pullman faculty through distance education. One of the major difficulties for the satellite campuses is providing appropriate laboratory experiences for students. There are several lab classes in the junior and senior years which require specialized equipment. The initial focus of delivering lab education to satellite campuses is the junior thermal fluids lab on measurement techniques.

There are three styles of laboratory experiments throughout engineering education: hands-on, simulation, and remote (or virtual) labs [1-6]. Hands-on experiments allow student to physically manipulate components and gather data. Simulations use computer software to emulate the results gathered in a real laboratory setting. Simulations can be successfully used to explain and reinforce physical concepts, but limit the capability for true experimentation. Remote labs use the positive features of both hands-on and simulation type lab environments. Simulation based labs cannot provide a "feel" for real things. Students need to use real devices and execute commands on real tools to gain necessary practical skills. Remote labs are similar to simulation techniques in the sense that they require minimal space and users can rapidly configure them over the internet. Unlike simulations, remote labs provide real data in which the user can adjust the input parameters. Although currently all of the experiments in the junior thermal fluids lab are of the hands-on type, the remote lab approach was judged to be the best solution for delivery of distance lab education to satellite campuses.

This paper describes the development, implementation, and testing of a remote laboratory for a thermal fluids lab on flow through a venturi and flow measurement. There are two intended users of the laboratory: students at satellite campuses will operate the lab remotely as part of their laboratory course and instructors will operate the lab from their classrooms to bring demonstrations and active learning components to lecture courses.

II. Approach

The development of the lab involved putting together hardware for the actual flow circuit, adding automated controls for valves, installing a web based data acquisition system, and integrating a web camera with controls.

A. Hardware and Plumbing

A schematic of the lab is shown in Figure 1. The on/off valve permits air to flow through the system. The flow control valve regulates this air flow. The air follows the piping through the filter, pressure regulator, and flow control valve (when open) and into the venturi to the orifice plate and out of the muffler. There are nine pressure taps along the venturi and one at the orifice plate as well as a thermocouple attached to the end of the muffler. All of these components are wired to an Agilent 34972A digital multimeter and power supply. The

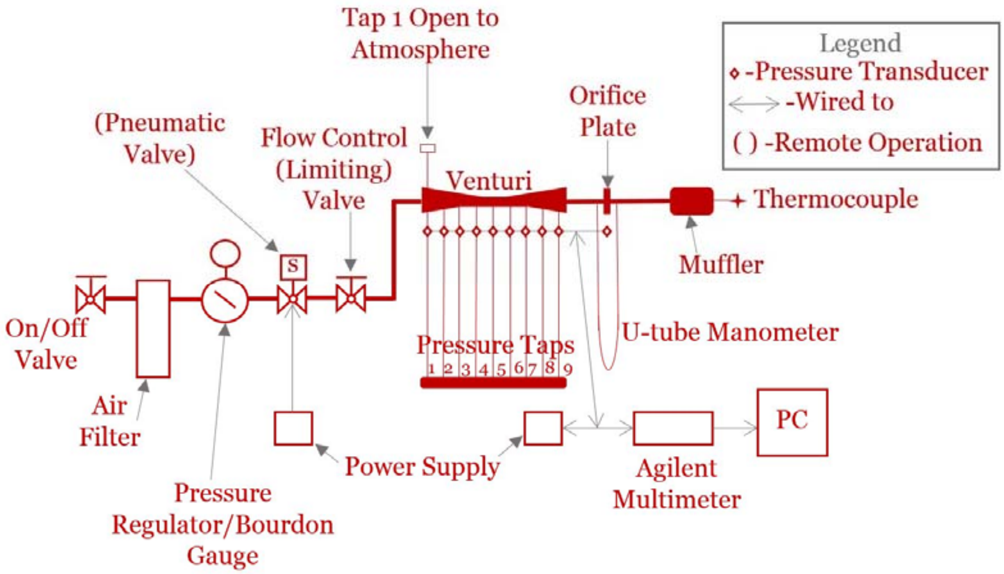

Figure 1: Venturi Flow Experiment Schematic

computer receives data from the multimeter in the form of voltage readings from each transducer. The orifice plate, used to determine the volumetric flowrate of air through the system, has a u-tube manometer attached to it. The u-tube manometer visually displays the pressure drop across the orifice. The muffler at the end of the flow circuit stifles the sound of compressed air through the system to a low hum while the thermocouple records the temperature of the air. A web-enabled surveillance camera (not shown in the figure) was also installed to allow users to view the experiment over the internet.

B. *Web Components*

An Agilent 34972A data logger was used for data acquisition and control. This data logger can be controlled by a web based graphical user interface. This allows students to use their personal computers to control the experiment and log data. The pressure transducers, thermocouple, and power supplies for the venturi experiment were wired to a 20 channel multiplexer module. The solenoid valve was wired to the multifunction module of the Agilent multimeter which allowed for remote control of the valve through the web interface. The solenoid valve, an Enfield Technologies M2D Pneumatic valve, was selected for its high speed switching capacity and flowrate range. It is installed in a basic open-looped proportional control configuration. A TRENDnet Wireless PTZ Network Camera (TV-IP612WN) was installed to provide visual access to the experiment. This camera has 10x optical zoom and 16x digital zoom with autofocus technology. The camera pans 330 degrees left to right and 115 degrees up and down. Users control the Pan-Tilt-Zoom functions remotely via a web interface.

C. *Running the Experiment*

Users may view the experimental set up by accessing the camera via a provided link. From the home screen for the camera students may zoom, pan, or tilt the camera to adjust their view. The display always has the date, time, and camera name stamped on it. After becoming familiar with the flow circuit students may begin experimentation. Users access the multimeter through a website with a link provided in the lab write up. From the home page they start by applying a voltage to the solenoid valve which opens the valve and permits flow through the system. Colored water rises in the manometers connected to the pressure taps along the venturi and provides a visual. The multimeter is then configured to collect the voltage reading corresponding to the pressure transducers along the venturi and across the orifice plate. The user may then vary the voltage to the solenoid valve to change the flowrate and collect the corresponding data. The collected data may then be exported to an excel spreadsheet for further manipulation.

III. RESULTS

The automated experiment was implemented in two settings. In the first setting an instructor used the remote lab in a lecture class on Fluid Mechanics to enhance student learning of concepts associated with flow through a venturi, Bernoulli's equation and the energy equation. In the second setting a pilot group of students enrolled in the junior lab at Pullman were asked to run the lab remotely and provide feedback and assessment of the experiment.

A. *Integration into a lecture classroom*

The remote lab was used in an active learning segment in the junior introductory fluid mechanics course. In this activity students collaborated on a worksheet designed specifically for the experiment. Students took a pre and post assessment quiz used to evaluate understanding of flow through a venturi before and after the exercise. The goal was to strengthen both procedural skills and conceptual understanding.

The lecture on venturi flow in the context of Bernoulli's equation was given the day before the exercise took place. Students completed an online quiz following the lecture which tested their understanding of the relationship between velocity and pressure in a venturi.

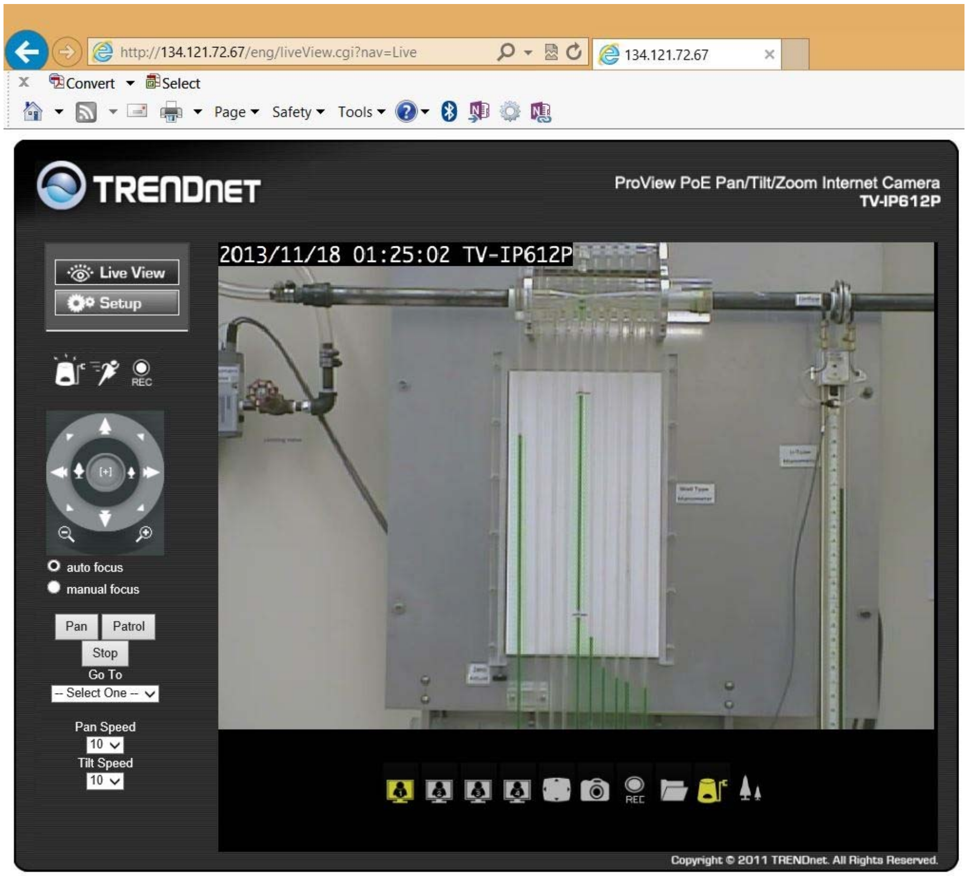

Figure 2: Home Screen, Student View

In the following class students were given the link so that they could view the experiment live on their laptops. The instructor controlled the experiment and projected the image. Students could observe the change in pressure along the venturi from the height of the colored fluid in the manometer tubes. They were then asked to perform calculations based on the experiment. The worksheet included a diagram of the venturi used in the remote lab, calculation questions, and conceptual questions. Students were given the flowrate and dimensions of the venturi section at the location of each pressure tap from which they calculated the corresponding velocity. They then completed a table using the experimental pressure data and the calculated velocites which provided a clear illustration of the relation between cross-sectional area, pressure and velocity of flow through a venturi. They also calculated the expected pressure along the venturi based on Bernoulli's equation and compared these pressures to the experimental pressures.

The assessment quizzes each had conceptual questions on flow through a venturi and Bernoulli's Equation. Although the questions on the two tests were similar, they were not identical nor were they ordered in the same way. The questions addressed the relationship between velocity and pressure, the points of lowest and highest pressure in a venturi, the points of lowest and highest velocity in a venturi, and when the application of Bernoulli's equation is valid.

Students had fifteen minutes to complete the pre-assessment quiz at the beginning of the class. After completing the worksheet and demonstration, students completed the post-assessment quiz. On the questions addressing characteristics of velocity with location 79% answered correctly on the pre quiz and 98% on the post quiz. On questions addressing the characteristics of pressure with location 37% answered correctly on the pre quiz and 81% on the post quiz. Sixty nine students took the pre quiz and 63 took the post quiz.

B. Integration into a virtual laboratory

The venturi experiment was run in the Pullman campus junior lab in the Spring of 2014. The majority of students performed the lab as a hands-on lab. A small group of eight students were selected to operate the lab remotely in a pilot study. Students performed the lab from somewhere else on campus or from home.

Students were given a task list specific to the remote lab that first guided them into the web camera user interface, and familiarized them with the pan-tilt-zoom functions of the camera. Students then use the camera to explore the different components of the experiment. A sample of the camera screen is shown in Fig. 2.

Next students accessed the Agilent multimeter through its web interface where they were guided through gathering data beginning with how to send a voltage to the solenoid valve to adjust the air flowrate. A window pops up where the user inputs a voltage between zero and ten volts depending on the desired valve opening.

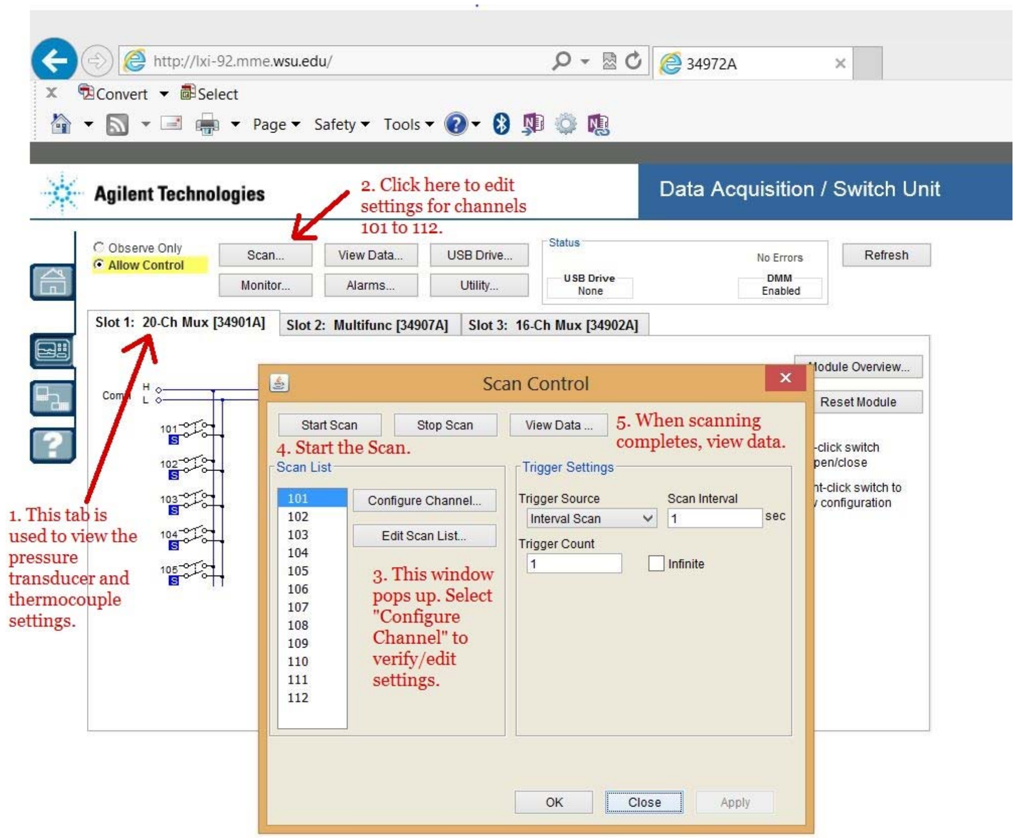

Figure 3: Configuring the Multimeter

Students then set up each channel of the multimeter, set a flow condition, and gather data at each flowrate. To set up the digital multimeter to read channels 101 to 112 (the pressure transducers and thermocouple) the user clicks on the appropriate tab in the window. They then select the “scan” button at the top of the browser, followed by the “Configure Channel” button. Figure 3 shows a sample of the window the student sees in this process.

The control group of students who ran the experiment remotely helped to pinpoint “holes” in the instructions and gave many helpful suggestions. Most of this feedback came through emails while they ran the lab. The rest came from the online survey they completed. The survey included the following questions: How would you rate the overall ease of operation? Were the screenshots showing how to operate the camera helpful? Was the camera image good enough to gather all the required data? Were the screenshots showing how to operate the multimeter helpful? And were the tasks listed in the handout easy to follow?

In summary, an experiment with web based control of and data acquisition from a model Venturi nozzle was developed and implemented into junior level engineering classes. Two major conclusions can be drawn from the implementation of the web-based lab. First, the pre and post test indicated that students showed significant improvement in conceptual understanding after exposure to the web-based lab in the junior fluid mechanics course. Second, the student survey indicated that only minor operational changes were needed for students to successfully operate the web-based lab. In follow on work, the remote lab will be offered at the satellite campus in the fall of 2014.

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A Discussion On Some Simple But Effective Methods On Keeping A Large Group of Students Motivated To Learn Any Engineering Subject

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***Abstract*— This paper outlines some simple yet effective techniques that have been applied in classroom settings, and found to be very efficient in enhancing students' learning experiences in both large and small classroom environments. It is needless to mention that there are neither rigid rules nor generalized scripts in streamlining this process; however, whatever method is tried out to enhance students' learning, has to be *entertaining*. Some of the methods include presenting a complex concept with analogies from everyday-life, remembering students' names and engaging them in discussions, bringing in some light-hearted humor during the lecture period, etc. Additionally, during the lectures, the students were told some humorous anecdotes relevant to the course, and this method was found to be highly effective in teaching the students some very fundamental concepts. Also, the well-accepted idea of giving the students a short break after every 20 minutes or so to re-ignite their interest has been practiced, where the students partake in well-thought, constructive activities during such break times. Instead of prohibiting students from using the smart electronic gadgets, they were persuaded to use those devices in an *intelligent* way, which in turn provided them a better learning experience. This paper elaborates all these ideas and finally presents some learning outcomes of the students.**

Keywords— Large Classroom, First year, Learning assessment;

I. INTRODUCTION

Teaching a group of students in any engineering program is always a challenging task for many different reasons: their diverse attention spans, the variable levels of motivations toward learning a new subject, and so much more. This challenge enhances manyfold if the class size is really large and, in this case, keeping the students interested in learning the subject becomes a difficult task for any instructor. Many researchers have pointed out the challenging aspects in teaching large classes. In [1] the authors reveal that there is a tendency amongst the students feeling isolated and anonymous in large class settings. These kinds of feelings amongst students result in lack of motivation in the learning process and, as a result, they tend to drift away from the learning domain by attending classes less frequently [2]. Similar research outcomes have been reported in [3].

Many researchers have put tons of ideas and thoughts on resolving the challenges in teaching large classes. The art of active learning and cooperative learning has been discussed in [4] as effective tools in handling a "*large classroom*" teaching environment. In [5], the author discussed some methodologies in teaching large classes effectively; most of these practices presented in [5] have been implemented in different universities in one form or the other. The interested readers on large class issues will find more information on this subject in the reference list provided in [5]. The report [3] prepared by Angelika Kerr also presented some interesting ideas collected from some notable teaching professors from different Universities; the principal challenge remains in not only how to teach a large class effectively, but also how to complete the syllabus on time with effective pace, so that this large group of students can retain the basic concepts they are taught in the course. We can come up with many different ground breaking ideas on teaching large classes effectively as long as we can implement these ideas in the best possible way within the given time-frame.

This paper will address some issues that may bring in the flavor of both time management and effective teaching in large class environments. Since it has already been demonstrated by many researchers (e.g., see [6, 7]) that student centered based teaching methods such as active learning, inquiry, problem or case based learning, discovery learning [8], just-in-time teaching [9] are the preferred methods over traditional teaching approaches, all the ideas presented in this paper are based on student centered based teaching methods.

The rest of the paper is organized as follows: Section II talks about some methods which were tried out in a large classroom environment; Section III presents some students' feedback on these methods, and the evidence of better learning outcomes; Section IV concludes the paper with some closing remarks.

II. METHODOLOGY

This section presents some methods that were attempted in large classroom environments by following some simple steps. These steps have been discussed briefly in the following subsections.

A. Get the students ready to be a part of the learning domain

This will be the first step in teaching a large class which is the most important step but, unfortunately, sometimes it is overlooked by most of us. This step can be accomplished by following some of the techniques stated below, which should be preferably followed on the very first day of class.

- *Create a family like environment*: Let our students know that we - the students and the instructor - belong to the same family in the classroom, where all the materials will be discussed in a friendly environment, so that all of us can *learn from each other*. We need to motivate our students in a way so that they can feel at home; sharing some honest moments will enlighten them, and in turn, will make them comfortable when it will come down to asking question or expressing ideas to the instructor.

- *Question-Answer policy*: If we plan to ask the students questions by picking them up by their names during a lecture, let all know about this approach. Also, let them know that if anyone is uncomfortable with being asked questions during the lecture, s/he can email the instructor to opt out of such scenarios, and in this case, the instructor should respect the student's choice. It is imperative to let the students know, that it is not dire that they put forth the correct response to any question the instructor may ask in the class. Also, let them know that if they can't answer any question you may ask, they can simply say "*pass*" without being ashamed because they're still inside the same family, learning some engineering concepts with clear understanding, so that they can apply those ideas effectively while working outside the family, which we call "*work domain*".

- *The old saying:* We need to make sure that they know the old saying: "*no question is a bad question*".

- *Know your colleagues/course-mates:* While in the class, ask your students to introduce themselves to their course mates sitting around them, because for the next four years (first year students) or so these family members will always stay close to each other. Encourage them to rotate their seats in every other week, which will initiate more bonding amongst them, and in turn, will make them good team players.

- *Course handouts:* Upload all the lecture handouts to the course site. This approach has huge advantages: the students can be ready with what to expect during the lecture and they can prepare some questions by reading those slides before attending the lectures. This practice will initiate both discovery learning process [8] and just-in-time learning process [9] amongst your students. If your students don't want to ask questions during the lecture, invite them to upload those questions to the electronic bulletin board. Also, you can bring a shoe-box in the class and ask your students to drop their questions in that box if they prefer to be anonymous. By studying these questions you'll know better what to focus on more during your lecture. This will save some lecture time for the instructor.

- *Exam Question Ideas*: Tell them that some of the problems you'll be discussing on the board alongside your electronic aided presentations (e.g., power point) may appear as exam questions. Also, tell them to pay attention during the lecture time because you'll be giving them hints on some exam questions while discussing some course topics.

- *Smart phone or any electronic gadgets:* Set the ground rule on smart phone or device use.

- *Make your students excited to learn the subject matter*: Let them know the wonderful engineering (and science) applications of the course materials you are teaching, and make them excited about it.

B. Retain your students' attention during lecture time

This will be the second step in teaching a large class which is always tried out sincerely by the instructors. The author tries the following methods to fulfill this task and finds some effective learning outcomes from his students.

- *Lecture management*: While presenting your lecture materials, instead of using either electronic media (power point slides, video presentations etc) only, or chalk/white board only, use the combination of these two mediums. In this case, always leave some unanswered questions on the power point slides (or in the video presentation) with a clear label saying "*in-class discussion*". Discuss these questions by interacting with the students using chalk/white board.

- *Track their attendance and make them comfortable*: Be very caring towards your students' learning interest. Try to stay connected to your students by tracking their attendance record. If you don't use any electronic method (e.g. clicker) to track their attendance, try using old school "*attendance taking*" method. Pass around the list of the names and get them to put initials beside their names. Study the list after the lecture and put an X-mark beside the names those who missed; remember some of those names. Check the class-roster with photos and remember the faces. Find out why those students missed classes and, explain the benefits of attending lectures to those students during your office hours or over email. Ask how you can make the learning environment better for those students so that they can attend the class. If any student does not want to attend lectures, after talking to you, respect his/her choice and suggest some methods so that s/he can prepare well for the exams. Send an email to the student(s) with some positive comments with utmost care.

- *Present ideas in a fun-filled way*: Bring in some current affairs, everyday life examples and constructive humor relevant to your course materials while delivering your lectures. Discuss some popular movie scenes and relate those to the concept you're talking about. While teaching a data-structure course, the author once mentioned about the characters from the comedy movie "*Harold and Kumar*", one of which is messy, while the other one is tidy. In explaining "G*reedy Algorithm*" the author once used the example of "*falling in love at first sight*".

- *Be passionate about your course*: Try to be very expressive in your emotions while delivering a lecture. Your students should feel your energy and they should be carried away by that energy. Present the course materials with vivid expression, body language and passion. Be yourself and vary your tone/voice when explaining some concepts to your students by making them engaged in this process. If you're explaining bridge design principles in civil engineering, be the "*bridge*" and play the role of a bridge with some other students in front of the classroom and, explain the design principles. The students will remember these principles better than hearing from you in technical language with a plethora of equations. These practices do not need extra resources or time, but need some simple, light-hearted thoughts. If you design your *thoughts* well ahead of time, you'll fly through it with ease. Using these practices you can effectively teach more information to your students in a shorter time-span.

- *Keep your students motivated to learn the subject:* In this case, knowing your students by their names will keep them motivated. Try to remember your students' names with the aid of the picture file provided by the registrar's office. Maintain a simple and relaxed atmosphere in the classroom environment. The author believes in the statement [10] made by a Computer Engineering freshman Shaun Wassell: "*The harder you push your brain to come up with something creative, the less creative your ideas will actually be. So far, I have not found a single situation where this does not apply. Ultimately, this means that relaxation is an important part of hard work—and good work, for that matter*". So the bottom line is as long as you keep it simple, the learning process will be very effective in any classroom. As an example, you can engage your students in the discussion by initiating it with a very simple question, you're sure that they will be able to answer and then take that question to the next level once you get their attention.

- *Draw students' in-class attention through carefully picked exam questions*: Set the first quiz/test questions from the problems you discussed on the board (aside from the power point slides) and, make sure you mention the date beside the question when it was discussed in the class. This technique worked really well for the author in keeping his students attentive during the lecture time. Example: Write a program to evaluate.... (This *question was solved on the board during the lecture hour on the 26th of February*). This technique will make every student believe that each lecture is worth attending.

- *Break-time idea - 1*: During your lecture time, give your students a short break with a question on the board and ask them to discuss amongst themselves to get the answer. Locate some area of the class where you find that the students are losing their attention and, ask a volunteer from that area to answer to that question. Once you get the answer keep that area busy with more questions. This will bring back their attention on the lecture topics. Also, during the break time, you can encourage your students to discuss the same issue that you just discussed in the class with their peers sitting beside them.

- *Break-time idea - 2*: During a short break in your lecture, ask the smart phone users to "*Google*" some interesting topics on the course, and based on the findings, ask one of the students to share that idea with everyone. In this case, there are two important things you need to pay attention to: first, you need to know the topic you're asking them to search and second, you need to follow the ground rule on the smart gadget usage.

- *Motivate your students to get the help of technology:* Encourage participation in the Electronic Discussion Board (EDB) by throwing a question. If anyone ask any question on the course related topic, instead of posting the answer to the EDB, post the hint to the board so that everyone can think-pair-share [3, 4]. In many occasions while teaching programming to the first year engineering students the author was able to generate mass interactions between the students by following this technique. This process will give the instructor an idea what to focus mainly during the lecture. Also you may ask your students to "*Google*" some of those concepts you discussed in the class, or find some "*YouTube*" information on those concepts to share with other students, so that they can hear the same information in a different way which may give them better grasp and/or understanding about the subject matter.

- *Make sure that your students have learnt something:* You need to let them realize that they've learnt something from this course. About the quarter way into the course, ask casually whether anyone thinks that s/he didn't understand anything from this course; if anyone says "*yes*", talk to the student in private, and motivate him/her to learn the subject; consider this as one of your own goals to make him/her learn something from the course. This way that particular student will be highly motivated and most of the cases will improve drastically. Try to repeat this procedure at least one more time before the midterm; after the midterm you'll have a good overall idea about your students' progress in the course.

III. RESULTS AND DISCUSSIONS

This section provides some results on the learning outcomes of the teaching methods tried out by the author in his classroom environment. Since the definition of a large class [3, 5] is completely dependents on some relative terms, such as student-teacher ratio, availability of resources etc., the results on the learning outcomes, presented in this paper, have been based on a class size of about 100 students. As suggested in [5] a short questionnaire was developed to evaluate students' positions towards the methods practiced in teaching a large engineering class. The sample results are shown in Table I. The average score, shown in the table, has been received out of 5.

Based on the responses received from the students, it can be concluded that the approaches tried out by the author worked well in the large class-room settings which enhanced the learning outcome of the students. But in this case, the result on statement 2 (see the table) requires little bit of discussion. Although uploading the lecture handout enhances the effectiveness of learning the subject matter for the students, as demonstrated in statement 1 in Table I, sometimes some students don't read the lecture handouts ahead of time (see the demonstrated result in statement 2 in Table I) for different reasons, such as time management etc. Also, the idea of giving out all the lecture handouts has a clear disadvantage. Some of the "*might be attending the lecture*"-type students don't feel like attending the lectures any more after they get all the course handouts for the course well ahead of time. They miss the point that the "*class lectures are offered for in-depth discussion on any topic presented on the lecture handouts*". In this case, the author uses a practice of contacting these types of students individually during his office hours, or during the lab sessions, and motivates them to attend the classes.

Since the quiz, lab and exam questions were the perfect reflection of the course materials discussed in the class (as demonstrated in statement 11 of Table I), every student was successfully convinced that each lecture was worth attending (as demonstrated in statement 6 of Table I) besides having some fun-filled experience (as demonstrated in statement 5 of Table I).

Table I. Students response on teaching approach

Statements		Average
1	Getting all the lecture handouts ahead of time was very helpful in managing the course and understanding it better.	4.75
2	Although the handouts were provided ahead of time but I didn't have much time to read the slides earlier due to my busy schedule.	2.7
3	The combination of the use of power point slides and the chalk/white board was helpful in understanding the course materials better.	4.8
4	Real life examples were helpful in understanding the complex concepts.	4.5
5	The concepts, presented with humorous analogies, were easier to understand.	4.5
6	Although the course materials were made available online ahead of time, attending the lectures were very helpful in understanding the concepts.	4.8
7	The relevant touch of fun and humor made the class enjoyable and enhanced my learning experience.	4.6
8	Frequent discussions on the review questions helped me focus on critical ideas.	4.4
9	The information on "*Might be in the exam*" issues during class discussion made me focus more on some of the concepts, a number of of which were asked in the exam.	4.45
10	Frequent pauses in the lecture for cross-discussion were very helpful.	4.4
11	The quiz, lab and exam questions were perfect reflection of the course materials discussed in the class.	4.55

IV. Conclusion

In conclusion, the author would like to draw the readers' attention to a key message identified in the report presented in [11]. The message says that there are qualitative differences in the way good teaching practice is enacted in large classes*: the number of students is not the critical factor, rather it is how good teaching principles are implemented*. The author believes in this message, and as a result, focuses on the implementation of good teaching principles by keeping it simple with a touch of fun and good humor; it's true that simple things are not always easy to implement, yet they are achievable. The old saying *"practice makes perfect"* is always true. In the classroom, let us call ourselves academic facilitators instead of professors or instructors. Excellent teaching approaches have been presented in different teaching-related journals, conference proceedings, formal and informal reports just to facilitate the learning process for our students. Let's follow one or more of those approaches based on our interest, need and choice in a fun-filled way. In this IT-based generation, we all are becoming machines, and that's alright. But, let us strive to be intelligent, colorful and humorous machines, with some human flavor, for this will surely make the learning environment more effective and rewarding, irrespective of the class size.

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Additive Manufacturing at a Distance: The Internet of Lab Things (IoLT)

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***Abstract*—The simultaneous rise of a) massively open online courses, b) the inexpensive additive manufacturing (three-dimensional printers), and c) emerging device internet connectivity and standards will converge on new methods of delivering online education to provide experiential learning. The author will present a brief review of the literature and discuss initial work on implementing a first year engineering design course that is proposed to go completely online.**

***Keywords*—online labs, massively open online courses, MOOC, additive manufacturing, 3D printing, open online labs, OOL, Lab as a Service, LaaS, internet of things, IoT**

I. Introduction

The popularity of massively open online courses (MOOC) and the emerging technology referred to as the *internet-of-things* (IoT) will foster the development of a missing key component of fully online courses: laboratories. While the concept of online labs is not new, the logistics and scalability of offering laboratories as a component of a MOOC have not yet been effectively solved. At the same time, perhaps one of the most notable pieces of current technology is the 3D printer for non-professional additive manufacturing. Additive manufacturing technology has achieved remarkably wide adoption for numerous applications at continually decreasing cost.

Over the last several years at McMaster University, the author has implemented the transformation of a traditional first year engineering Design & Graphics course from its focus on *form* to *function*. In doing this, the course implemented an engineering design project that required the students to design and manufacture a function gear-train that would retrofit an existing product under new space and time constraints. This approach to experiential education has been extremely successful in engaging the students and at teaching the design curriculum.

Recently the provincial government of Ontario, Canada launched an initiative to take a number of post-secondary courses completely online (Ontario Online). Given the success of the new Design & Graphics teaching approach the author's course was selected for consideration. This paper's purpose is to share considerations of how such an objective could be accomplished.

II. Background

The first year Design and Graphics course at McMaster University is part of a common year. The course runs in the Fall and Winter terms with approximately 1000 per year and is structured with lecture, lab, and tutorial each week.

Since 2006 the course has evolved from the more traditional focus on CAD and hand sketching, to incorporate dissection [1], mechanism design, system modelling [2] (see figure 1), and rapid prototyping [3] (see figure 2).

While most students become adept at using CAD software, the traditional assessment focus on the *form* of a design results in many students that have little functional understanding of the parts and assemblies they are modelling. This result highlights the problem with many traditional graphics courses because the emphasis of assessment is based on the mechanical form and not on the function. In part, this is the result of increased class sizes, limited resources, and insufficient tools. The incorporation of a system modelling tool for visualization and simulation into traditional design and graphics courses permits students to gain insight into the mechanical *function* of the mechanisms they are creating.

To extend the course beyond the traditional focus, the author started with developing a simulation component to facilitate the "what-if" and the validation of calculations. Pedagogically simulation was very effective and well received by the students; however, it added a layer of visualization that the author felt could be addressed by allowing students to physically build their designs. The additive manufacturing process was added and students were then able to physically create their designed parts.

In order to facilitate the existing "brick and mortar" course, the author employs an online Learning Management System (Avenue2Learn). Excluding the sketching assignments, all course assignments are delivered, collected, and graded online. All lecture, lab, and tutorial notes and supplemental materials are also online. From the course delivery perspective, there are many MOOCs that have solved the teaching aspect. Thus it is only the 3D printing presents a challenge.

A. *MOOC – Massively Open Online Courses*

The MOOC originates from idea of Open Education and has gained its recent prominence from the three largest

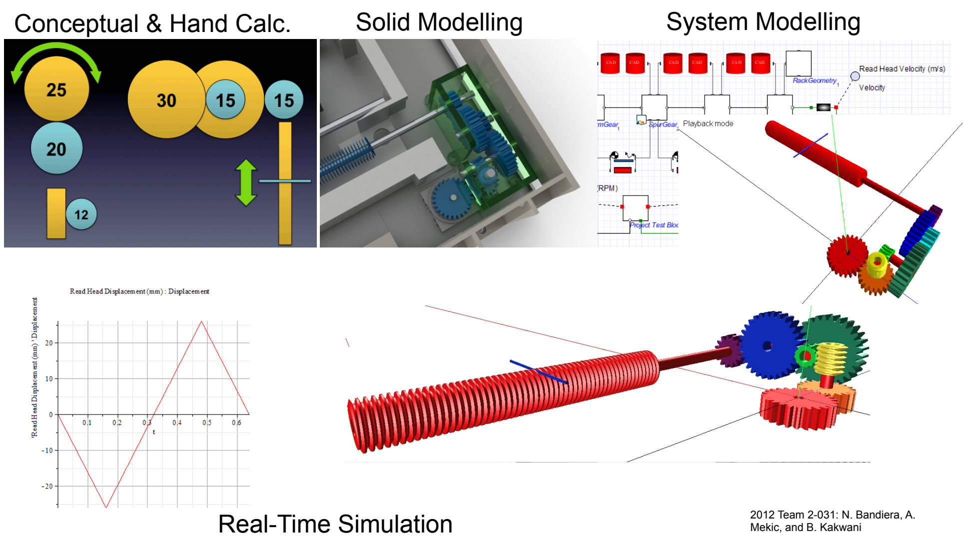

Fig. 1: The student design process from concept to simulation.

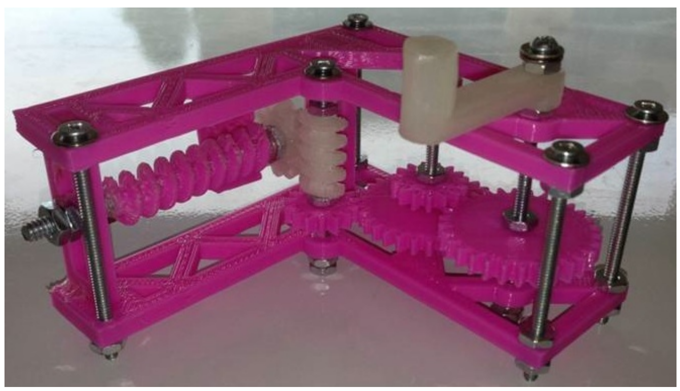

Fig. 2: The student 3D printed gear train.

providers of courses: Coursera, edX, and Udacity [4] [5] [6]. Figure 3 by Yuan and Powell illustrates the timeline of the MOOC development.

B. Online Labs

Online labs are not a new concept [7], but the term perhaps requires some clarification. In this context an online lab is the interfacing from a student's computer (remote) to equipment within the "lab" to replicate physical manipulation. Certainly an online lab could be performed fully online, but it depends on the course (e.g., a programming course). Traditional hardware labs (e.g., circuits, controls, etc.) are now seeing interface devices that permit remote measurement and manipulation, but systems are proprietary and scalability is a concern.

C. IEEE P1876 Standard

If online lab communications were standardized, similar to the IEEE P1876 proposal, then the concept of online hardware labs becomes attainable and scalable. The IEEE P1876 is for Networked Smart Learning Objects for Online Laboratories with the scope to define methods for storing and retrieving learning objects for remote laboratories and to define methods for linking learning objects to design and implement smart learning environments for remote online laboratories. Its purpose is to ease the design and implementation of pedagogically driven remote laboratory experiments [8].

D. IoT – Internet of Things

The *Internet of Things* [9] [10] [11] is the deployment of low-cost, embedded telematic network sensors that can operate in parallel. The application of such devices is rapidly growing and evolving along with their communication standards. Figure 4 by Atzori, Iera, and Morabito illustrates the overlapping domains that are collectively forming the IoT. The communication standards are tailored to the type of interaction/interfacing required for these low powered devices. Figure 5 represented an example of the IoT architecture similar to the standardized Open System Interconnection (OSI) network layer architecture.

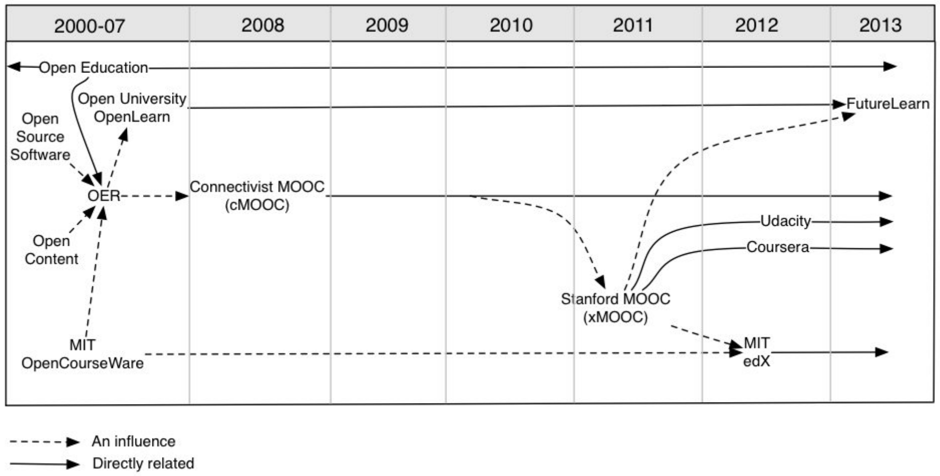

Fig. 3: Timeline of the MOOC by Yuan and Powell [6].

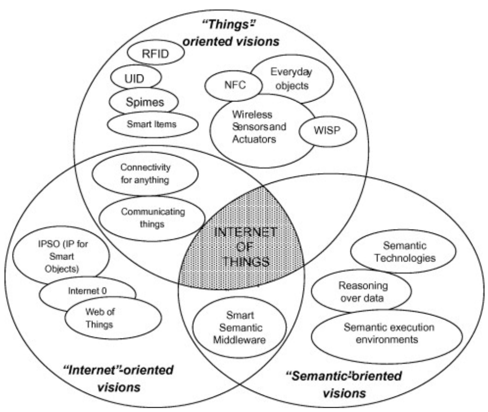

Fig. 4: Internet of Things paradigm as a result of the convergence of different visions by Atzori, Iera, and Morabito [9].

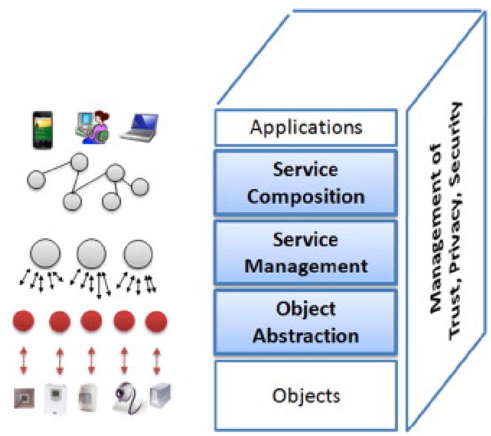

Fig. 5: Example of Software Oriented Architecture for IoT by Atzori, Iera, and Morabito [9].

E. Rapid Prototyping – 3D printing

Rapid prototyping is currently transitioning from hobbyist novelty to mainstream consumer interests. It has now become possible to visit a UPS store in the United States and have your designs fabricated on a professional 3D printer, similar to how you would have a report copied and bound. The costs of these machines has dropped as low a few hundred dollars, with today the ability to purchase for $1000 what would have recently been a professional prototyping printer. Print technology is also evolving. The most common type is still filament based made of PLA (polylactide) or ABS (acrylonitrile butadiene styrene) thermoplastic.

III. Taking It Online

Taking any course fully online is a significant commitment and investment. While the role of the Learning Management System appears to be moving toward the MOOC model, a completely online course is much more than recording physical lectures. What were once 1 lecture hour blocks are now focussed into multiple 10-15 minute segments with active learning components. Logistics and development time are major factors in a successful implementation. The context and expectation of the course dramatically effect development costs, which are reported to range between $40,000 and $325,000 [12]. What is now being addressed by researchers is how to offer such a course when access to physical equipment is required, such as in many engineering courses [13].

A. OOL – Open Online Labs

In connection to the MOOC, a massively open online lab (or MOOL) seems a natural extension, but in fact the term conflicts with what MOOCs represent in terms of being *massive*. Labs are typically limited by resources and by their nature not always *open*. In this way scope and scale must be factors and a decision as to if a fully online course is intended for students from a single institution or students from around the world.

IV. Discussion & Conclusion

The development of standards such as IEEE P1876 and IoT will drive the development of Open Online Labs and likely become known as LaaS (Lab as a Service) [13]. However, until this area of research and development mature beyond its infancy the IoLT will remain only a vision with existing non-standardized efforts significantly limiting the effectiveness of such labs for open online education. The field of additive manufacturing is at the stage where the technology exists to remotely interface with the printers, but this too is non-standardized and thus limited.

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“Big-DATA” processing tool for students

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***Abstract*—Today anyone can download "Big-Data" and tools from few software companies. How to make students to capture the concrete concept of "Big-Data" is also a big interest in our education. We propose that "Big-data" can be viewed as a set of features for students. And we also design the software that presents the features are useful tool for big data processing. The purpose of this proposal is to emphasize the fact that there are experiments proving the relationships between feature and big data analysis. We are going to conduct an experiment, with a gradual application, to show how features can pick up the data that we want in order to demonstrate its relationship. We used the Twitter data that has been collected from several millions of people and we used total of 10 features for processing. And we demonstrate that the combination of features can be an excellent tool to pick up the required data and show special characteristics of features through the experiment. Finally we will display the relationship in the experiment by evaluating our method of calculating precision and recall.**

***Keywords*—Big-data, Twitter, Precision, Recall**

I. INTRODUCTION

Big data is defined as large and complex data sets which are difficult to process with standard software [1]. These days, data sets grow as bigger than ever. The one of the reasons is that the growth of smartphone user has been tremendous. The smartphone subscriber reached approximatley1.9 billion and expect to reach 5.6 billion by 2019 [2]. Besides, in the field of aerial sensory technologies and wireless sensor networks, the size of the data sets have been growing bigger as well [3] [4].

Big data has unlimited potential and already used in the various areas. For example, Barack Obama`s successful 2012 re-election campaign was helped by big data analysis [5]. The NASA keeps 32 petabytes of climate observations and simulations on the Discover supercomputing cluster [6].

Furthermore many enterprises also pay attention to big data because it can improve their business operations. When big data is effectively captured, processed, and analyzed, then companies are able to gain better understanding of their business, customers, products, and competitors. In particular, enterprises invest heavily on the analysis of big data in SNS. According to IBM Global CMO Study in 2011, marketing executives in high rank companies in the world expect to accurately anticipate future by utilizing SNS. IBM`s report indicates importance of understanding customer sentiment through big data created on SNS. It leads directly to better customer service and improved products. It naturally creates increasing in sale ultimately.

In this paper, we think it is important to describe relationship between big data and features through an experiment on twitter to capture the processing concept for students.

II. METHODOLOGY

We will describe the strong relationship between big data and feature by an experiment. The experiment is to apply text mining to Twitter, which is the most popular social network service that has over 500 million active users and generates over 340 million daily tweets in 2012 [7]. We collected tweet data for the experiment by using Twitter API.

API is a kind of regulation when connecting to a server. Most famous web servers such as Twitter and Facebook provide their own API. Twitter API helps developers who desire to apply twitter data to make access with a lot of useful functions. However, a permission must be obtained if you want to use Twitter API. You can connect Twitter Developers site (https://dev.twitter.com/) and affiliate to create a new application and finally you can obtain an API key. We developed an application with JAVA so we used Twitter4J library (http://twitter4j.org/ko/index.html). It helps to develop an application without processing JSON or HTTP. Twitter API can be divided into two parts: the search API and the streaming API.

The search API allows queries that can discover the tweets we want to extract. For example, it can easily search famous athletes’ tweet. However, there are some limitations. The main limitations are predefined data effectiveness and the amount of the data that they provide. It returns the tweet created in between 6 to 9 days and can make only 180 queries per 15 minutes.

The streaming API allows high-throughput near-realtime access to various subsets of public and protected twitter data. There are three types of streaming API; public streams, user streams and site streams. First, the public streams presents the public data flow through Twitter. It is good for data mining. The user streams is to provide single user`s view on Twitter. The site streams is the multi-user version of user steams. Site streams are intended for servers which must connect to Twitter on behalf of many users.

The Experiment is classifying news tweets and other topic tweets by using 10 features through an educational tool we made. These features are selected after investigating news and twitter characters.

III. FEATURES

We are using 10 features for the experiment. We studied the twitter data and news information for finding distinct characteristic in them and we are going to use them as features.

First feature is the 'retweet' function in the twitter. Retweeting can simply be seen as the act of copying and rebroadcasting. When you re-publish something that another twitter user has written which you are also interested in, you might spread the words to your own twitter followers. Many people tend to mainly retweet a tweet about breaking news [8]. For this reason, we choose retweet function as a feature. We collected total of 5099 news tweets and 5069 of tweets are retweeted among them.

Second feature is a twitter function as well. It is the 'Hashtags' functions. When launched in March 2006, twitter did not have the hashtag function. Twitter users only could share their message with their follower who have agreed to receive tweets. So many users thought that twitter needed tagging function. Mr. Chris Messina who early twitter user suggested hashtag use by adopting the Internet Relay Chat (IRC) convention in 2007 [9]. The '#' symbol called 'hashtag' is created manually by Twitter users and it is used to categorize tweets in order to search and share information. For example, one can search for '#bible' and then get the set of the tweets related to the keyword 'bible'. Take news as an example. Users usually annotate breaking news tweets with a hashtag as '#breakingnews' [10] and can find news tweet with keyword #breakingnews.

Next feature is an URL that is the entrance to the whole information. Twitter has a special function that limits a tweet to be less than 140 characters. It helps to amplify the rapidity of the information exchange and promote easily digestible information [11]. However 140 characters are too short to accommodate a full new report, so news contains usually an URL to refer to the original article [12]. However, some URLs are long than 140 characters. Therefore, Twitter also supplies automatic URL-shortening services for overcoming 140 character limit.

We selected emotional words as a feature because news are tend to be reported without bias and emotions while commentators and analysts provide their opinions or personal point-of-views. News reports are always expected of objectivity [13].

A proper noun such as the name of celebrities, city and countries is a one of the important feature to find news [10]. News normally is composed by 5W and 1H; When, What, Who, Where, Why and How [14]. Who and where can be the proper noun such as Obama, Rome, and China.

Next feature is slangs and shortenings. News is published generally after checking spelling and grammar whereas other text like personal messages tend to often use slangs and shortenings [13].

We extracted the verbs that are especially used many times in the news tweet like 'bomb' and 'survive' for another feature [10]. The process is needed for the experiment of the feature. In the experiment, the first step is to collect approximately 1500 news tweets and another 1500 tweets of other topics then performing POS tagging with Stanford Parser for extracting verbs. POS tagging is a process of making up a word in a text as corresponding to a particular part of speech, based on both its definition, as well as its context. After that, it chooses some verbs which are used a lot in only news tweets through comparing the news tweets and other topic tweets.

The last feature we used is the SentiWordNET 3.0 which is a lexical resource. SentiWordNet is devised for supporting sentiment classification and opinion mining. It annotates all the synsets of WORDNET with positivity, negativity and objectivity. Each of these attributes is associated to numerical scores.

Table 1. Sentiwordnet example of a word 'only'.

Pos	Sense	Pos	Neg	Obj	Example
Adjective	Only#1	0	0	1	An only child
	Only#2	0	0	1	I`ll have this car and this car only
Adverb	Only#1	0	0	1	He was only a child
	Only#2	0.25	0.25	0.5	A privilege granted only to him
	Only#3	0	0.25	0.75	We won only to lose again in the next round

It is publicly available for research purposes and used more than 300 researches and a wide diversity of projects worldwide [14]. It is composed of 4 part of speech; noun, adjective, verb, and adverb and the total number of synsets are 147,278. The objective words are helpful to extract news tweet because news information has an inclination to be neutral. So we collected all synsets which are always objectivity score 1. The total number of the synset is 107,560.

Table 2. Example of a word that is always objectivity.

Pos	Sense	Pos	Neg	Obj	Example
Noun	Town#1	0	0	1	They drive through town on their way to work
	Town#2	0	0	1	The whole town cheered the team
	Town#3	0	0	1	The town is responsible for snow removal

IV. DATA

The experiment data was collected by using both the search and streaming API. We collected news tweets and some were not news topics tweeted by search API because if we use only streaming API for collecting tweet data, most of them could be chats during tweets. It may cause unwanted result. So we collected some tweets from special accounts like politician, wise sayings, and so on and then used them as out of news tweet. The data in the experiment was restricted to only English tweets and excluded greeting tweets (i.e good morning) and the tweets just included only an URL. The number of the data for experiment is almost 10,000 tweets (9962) and labelled with the two categories (news 5099, out of news 4868) for the experiment.

V. CHARACTERISTIC OF FEATURE

The experiment with the 10 features exhibits the chief characteristic of feature and relationship between feature and big data. The experiment is text classification between news and others. First, we will show feature`s special character through the experiment. Text classification is generally evaluated by precision and recall. Precision is the number of the correct results divided by the number of all returned results. And recall is the number of correct results divided by the number of results that should have been returned.

The Experiment is conducted with Naïve Bayes Classifier
First of all, we used only one feature city for classification between news and others.

Table 3. Result of using a feature.

Feature	Precision	Recall
City	0.262	0.512

The score of using a feature city is very low in totality. Particular precision is very poor 0.347. However, we use only one feature of ten features. Next, we tried to add another feature country.

Table 4. Result of using two features.

Features	Precision	Recall
City and Countries	0.742	0.571

Table 4 refers to highly increased score compared to use of one feature city. We have added just one feature country. The score of recall slightly increase by 0.059 while precision was rapidly increased to 0.742. The combination of two features achieve fairly suitable score. Table 4 represents that appropriate feature can increase the performance of big data`s analysis as well. We attempted to improve performance if we use three features; cities, countries and slang.

Table 5. Result of using three features.

Features	Precision	Recall
City, Countries and Slang	0.742	0.571

Surprisingly, all scores of precision and recall in the table 5 are unchanged although we add a feature, slang. From this result, we can understand the feature ‘slang’ is totally ineffective. We can set up a hypothesis that slang is irrelevant feature for news from Table 5. So we are going to experiment to confirm our conclusion.

Table 6. Result of using all features and all features – slang.

Features	Precision	Recall
All features	0.839	0.835
All features without slang	0.837	0.832

The results are shown in table 6. To begin with, we perform two experiments using all 10 features and 9 features excluded the slang feature for verification of whether slang is irrelevant feature or not in news. Table 6 shows that the score for all features is higher than 9 features. The two scores mean that slang is not irrelevant feature for news because there is score gap between all features and 9 features. We can see changing the influence of the feature slang different conditions because the feature`s special characteristic is a tendency to depend on other features used at the same time.

VI. ANALYSIS

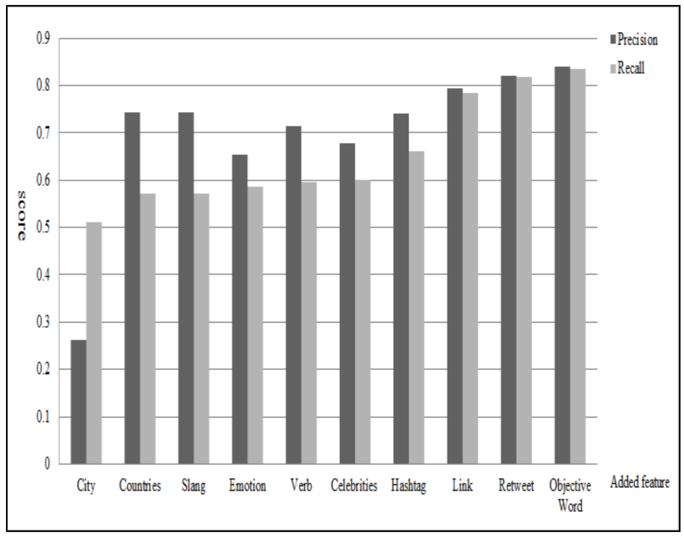

Fig. 1. Graph of Experimental result.

Figure 1 shows each scores of precision and recall when added one more feature alternatively. As the graph depicts, the score does not always increased sometimes decreased. It shows that combination of features can controls performance of the big data processing. When add an emotion feature, the score of recall is slightly increased while the score of precision is decreased. On the other hand, when we apply the link feature, both scores increased significantly. Particularly, the score of recall grows so much more than 0.10. It certifies that the link feature is excellent to assort the data into two groups; news and out of news tweets. The best score that using all 10 of features is especially higher recall when compared to other group`s experiments. Particularly, the score of recall grows so much more than 0.10. It certifies that the link feature is excellent to assort the data into two groups; news and out of news tweets. The best score that using all 10 of features is especially higher recall when compared to other group`s experiments.

VII. BIG-DATA ANALYSIS TOOL

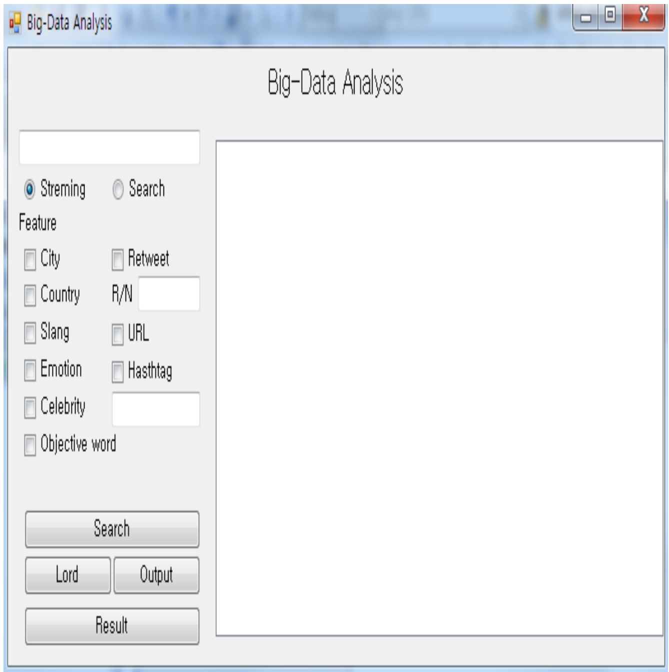

Fig. 2. Big-DATA Analysis tool.

We design an educational tool "Big-DATA Analysis" based on the concept that the features are useful tool for big data processing. The search button is to collect tweet by using Twitter API. If using search API, the number of tweet is limited each query maximum 1500 where Streaming API is not. The output button is to file collected tweets for result button. The lord button is to lord outputted file for processing. The result button is for evaluating classification

VIII. CONCLUSION

In this paper, we discussed how big data can be easily treated by features, and show the way to analyze big data with our idea through the experiment. The experiment shows that relationship between big data and features for student to understand big data processing by evaluating precision and recall. In addition, the educational is helpful for students to learn Big-Data.

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SELECTING RESEARCH STAFF USING A MODIFIED BEHAVIOUR DESCRIPTION MODELLING (BDM) APPROACH

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***Abstract*—Academic and research program administrators can relate to the challenges and risks associated with the recruitment and selection of capable personnel to their teams. Selection decisions should lead to hiring qualified candidates and avoiding applicants that manage to present well only on paper and/or during interviews. Unstructured interviews permit extraneous factors (including emotion, bias, premature decision making and basing decisions on irrelevant information) to unduly influence the selection process leading to poor choices. The employee selection literature informs that a range of techniques can improve the probabilities of hiring high performance employees through the use of: multiple panel interviews, multiple raters, reliable/valid selection instruments, realistic job previews and structured interview methods including behaviour description modelling (BDM) or situational interviewing. Structured approaches to employee selection reduce procedural variance across applicants by limiting rater discretion.**

This paper presents an alternate selection approach relative to traditional models which typically involve securing CVs, conducting interviews, and choosing 'successful' applicants. The proposed method developed a set of BDM questions aimed at promoting higher levels of self selection, identifying candidates possessing domain knowledge, evaluating innovation and critical thinking, and assessing applicant communication skills (both oral and written). Adopting a two step process, candidates completed an open ended questionnaire, which was built upon research project requirements. Candidates' submitted responses that aligned well to the BDM based selection criteria were invited to proceed to step two, which involved successive, multi rater, formal, structured interviews.

Lessons learned and best practices arising out the immediate experience will be shared.

Keywords—behavior description modeling, decision making, personnel selection, reliability, situational interviewing, structured interviews, type 1 and 2 errors, validity;

I. INTRODUCTION

Often operating with very limited budgets, small grant funds, and tight time frames, university researchers hastily and expeditiously hire graduate students and post doctoral fellows to satisfy specific job requirements. A persistent and enduring challenge within the human resource assessment literature arises out of the inability to consistently predict job performance after subjecting candidates to selection processes, typically, an unstructured interview. Exacerbating the selection problem is the notion that the process of choosing people to populate an organization tends to be executed in rather haphazard and unsystematic ways where two types of errors can occur - choosing people who should not have been offered the job while allowing promising candidates to be recruited by competing organizations (Type 1 and Type 2 errors) [1]. Further, unstructured approaches expose researchers to a range of potential hiring mistakes and biases including: primacy/recency, halo/contrast effects, similar-to-me bias, first impression error and other cognitive heuristics [2, 3].

Compounding the challenge, most researchers typically receive little (or no) training in the area of personnel selection, as such activity is viewed as little more than an exercise in common sense. Yet practicing and seasoned managers advise otherwise counseling that choosing capable personnel can be among the most challenging aspects of their jobs.

A broad range of psychometric tools and approaches to employee selection have been identified across 100 years of personnel selection research beginning with officer screening in World War I [3, 4]. Early psychological tests administered to millions of American soldiers to identify those possessing officer potential failed to exhibit high levels of validity [4]. Over succeeding decades, psychological tests and other evaluative methods demonstrated considerable instability in terms of reliability (the degree to which successive administrations of the same instrument yield a similar result) and validity (a measure of the effectiveness of a given approach across settings) to the point where overall utility has been cast into serious doubt [4].

II. UNSTRUCTURED / STRUCTURED INTERVIEW

In an effort to identify the most suitable candidate for a given position, an enduring and broadly applied practice involves the face-to-face interview. Such practices can be conceptualized as anchored by the unstructured interview on one end with structured interviewing representing the other end.

As a matter of competing priorities and day-to-day organizational rhythms/realities, most academic researchers entrusted with hiring personnel possess neither the requisite training nor are they able to devote the necessary time and energy to prepare for and execute a 'proper' hiring sequence or process. To the extent questions are asked spontaneously, questions vary across candidates, and responses are not evaluated in any consistent manner, an unstructured interview is tantamount to an unplanned, casual discussion [5]. Further, the unstructured interview permits factors unrelated to job requirements to creep into the decision making process effectively undermining the validity of the single job interview approach. Extraneous factors such as emotion, bias, rapid/premature decision making and inclusion of irrelevant information cloud the ability to make a quality selection choice resulting in needless distraction and frustration for all parties involved. Despite these problems, this brand of ad hoc interviewing, remains the most widely favoured and used method for assessing job candidates [6].

On the other hand, structured interviews are based on a thorough analysis of job requirements required to perform the work. Candidates are asked the same questions with responses systematically assessed against job-relevant criteria using predetermined rating schemes. The intention is to establish a clear linkage between performance at the interview and anticipated performance on the job by subordinating the impact of personal bias/error on the assessment process. Structured interviews are further characterized by careful planning reflective of: multiple raters, multiple interviews, behaviourally/situationally stated questions, consistent administration of questions, immediate rating of respondents and subsequent peer discussion.

Evaluating the utility of various interview processes, in a broadly cited literature review, Wiesner and Cronshaw report low to moderate validity values for unstructured (r = .2) versus structured interviewing (r = .7) [5]. Similarly, Schmidt and Hunter's 1998 meta analytic study of a spectrum of personnel assessment devices and approaches found lower validity for unstructured (r = .38) when compared to structured approaches (r =.51) [7]. The same researchers reported that predictive capabilities of structured interviews can be further enhanced when used in combination with other selection methods (Table 1).

In conclusion, the preponderance of studies recognize the value of structured interviewing over unstructured with considerable variation attributed to other interviewing and situational factors [5, 8].

III. GENERAL PERSONNEL MEASURES

In a widely cited literature review covering nearly a century of personnel assessment, Schmidt and Hunter, indicated that general mental ability (GMA) as captured by intelligence or general ability aptitude tests possessed among the highest validity and greatest stability for the prediction of job performance across a spectrum of positions [7]. Other significant predictors of job performance included: training and education behavioural consistency methods, work sample tests, structured employment interviews, peer ratings, and job knowledge tests. However, considerable variation has been observed in the stability of predictors as a function of varying job situations calling into question the validity generalization of many methods (Table 1).

Table I. Validities by Personnel Measure [7]

Personnel Measures	**Validity (r)**	**Incremental Validity**
GMA tests	.51	
Work sample tests	.54	.63
Integrity tests	.41	.65
Conscientiousness tests	.31	.60
Structured interviews	.51	.63
Unstructured interviews	.38	.55
Job knowledge tests	.48	.58
Job tryout procedure	.44	.58
Peer ratings	.49	.58
T&E behavioural consistency method	.58	.45
Reference checks	.26	.57
Job experience (years)	.18	.54
Biographical data measures	.35	.52
Assessment centers	.37	.53
T & E point method	.11	.52
Years of education	.10	.52
Interests	.10	.52
Graphology	.02	.51
Age	-.01	.51

Table 1 also reveals the incremental improvements that result from combining assessment methods to produce cumulative validities. The table also illustrates the incremental or combined validities of complementing general mental ability (GMA) with other selection instruments/approaches. For example, utilizing both GMA methods and structured interviews elevates r from .51 to .63, a 24% improvement.

Particular approaches to selection enjoy temporary adoption but fall out of fashion when meta analytic or literature reviews report overall poor validities. For example, Guion and Gottier concluded that "the best that can be said is that in some situations, for some purposes, some personality measures can offer helpful predictions" [9]. As a reflection of its consistently poor empirical performance in predicting job performance (r = .02), graphology (handwriting analysis) has been identified as not being predictive in any meaningful way and repeatedly labeled pseudoscience [10]. Taken alone, many job performance predictors have failed to significantly improve personnel decision making and helped usher in the situational specificity hypothesis [11].

While the validity associated with any given approach/method may be low, the predictive power of an overall selection process can be improved by combining selection methods into an overall strategy, thus yielding higher incremental/cumulative validities [7, 12]. Applying an experimental design, Wiesner found that the combination of "a highly structured interview, utilizing job-relevant questions, the answers to which are scored as they are given using a scoring guide" yielded a validity of .85 [13].

IV. BEHAVIOURAL DESCRIPTION MODELLING

Structured approaches make provision for the inclusion behaviourally presented questions. Behavior description modelling (BDM) theory rests on a presumption that future job performance is predicated on past behavior (how a person has performed/behaved in the past is suggestive of how they will react in future situations). Accordingly, interview questions are structured across a number of job performance dimensions placing the candidate into job relevant ‘circumstances’ prompting responses in terms of how they would intend to react or respond to the presented situation [6].

A variant on BDM, situational interviewing (SI), is based on the premise that candidate intentions predict behavior [8]. SI is employed in circumstances where the candidate draws on a parallel or roughly equivalent situation to answer a question where they themselves have never been directly involved with the circumstance being queried. The situational question permits an exploration of how candidates would extend their basic knowledge/experience into the realm of new challenges demonstrating adaptability, flexibility, creativity, and critical thinking. For academic research, where a premium is placed on discovery and exploration, the situational question can be invaluable in identifying suitable candidates (summer, co-op, graduate and post doctoral fellows).

As an illustration of BDM versus SI questions:

Sample BDM: Tell me about a time when a research program you were involved with appeared to be falling behind schedule. What did you do and what was the result?

Sample SI: Based on your research activities to date, indicate areas for potential commercialization of the ideas you have come up with and indicate you how you intend to pursue implementation.

Both the BDM and SI have demonstrated their empirical efficacy in interview processes [8, 13]. Used in combination to probe a spectrum of job related dimensions should improve the predictive validity of structured, behaviourally based approaches to candidate assessment.

V. BDM/SI APPLIED TO ENGINEERING RESEARCH PROGRAMS

A case has been made that empirically validated methods for improving the predictive capability of personnel selection methods are available to the research director. Choosing the wrong person benefits neither the researcher nor the candidate while overlooking qualified applicants weakens the research program overall.

The section which follows sets out a suggested process that researchers can utilize to improve the probabilities of hiring suitable candidates to populate research programs. The fundamental premise within the suggested process begins with the requirements of the research grant application document. Whether applying through NSERC, FedDev, CFI or other research avenues, considerable research, thought and editing are required to put forward a winning proposal. Grant applications are typically quite specific and limiting (with enforced word/page restrictions) demanding that applicants be clear and concise with response articulations. Having completed and succeeded in securing funding, the principal investigator is in possession of both questions and answers that can be used in interviews.

Figure 1 below provides a process for improving the likelihood of identifying successful job candidates in support of a research program.

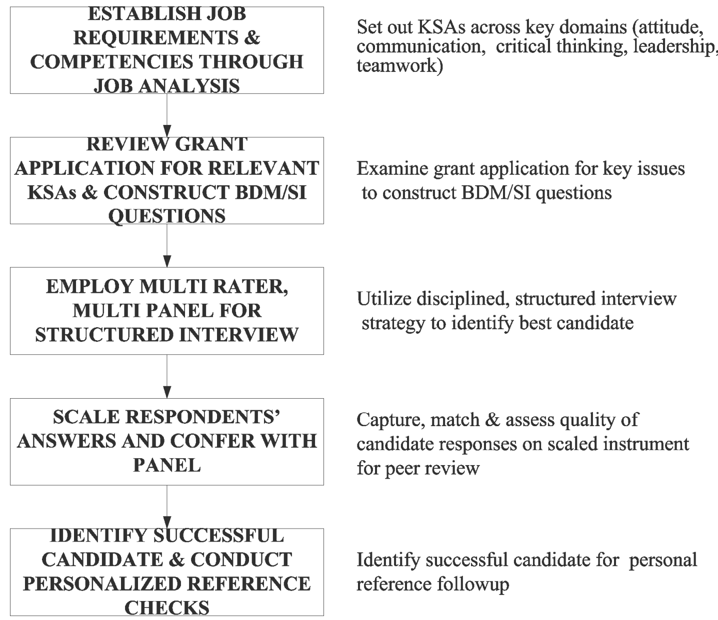

Fig. 1. Suggested Selection Approach

VI. CASE STUDY

The authors of this paper have recently been involved with a major government grant application for research in the area of smart grid. Based on grant application requirements, a structured approach for selecting and hiring co-op/graduate students was developed. The premise behind this approach was that grant application questions possessed considerable content validity and the ‘answers’ were known to the interviewers since such responses had been provided as part of successful grant application. Job candidates’ responses could be compared to the ‘answers’ provided by the grant applicants.

1. Projects and tasks associated with the research grant gave rise to a list of the required knowledge, skills and abilities (KSAs) across various positions.
2. A set of BDM and SI interview questions was created as per the application document, feedback from the granting agency and other evaluating bodies as part of the due diligence process.
3. Multiple interviewers were assigned across various projects as a reflection of their technical expertise and experience. As a practical matter, given the entry level of the positions to be filled, second level interviews were considered unnecessary.
4. During the conduct of the multi rater interviews, rating scales were employed to score applicant responses. Collectively, raters conferred and made final decisions.
5. As a variant on the basic hiring process described in Figure 1, a personally conducted reference check yielding a positive recommendation, triggered the issuance of a three employment month contract. Such a short term appointment

permitted candidates to demonstrate their technical competence, team skills, leadership capability and other job related factors. Those showing satisfactory performance were offered longer terms of employment.

The process outlined above resulted in the hiring of five students (2 college co-op and 3 masters level) who are showing themselves to be valuable, contributing members of the research team.

It should be noted that the previous discussion has addressed the hiring of local candidates. In the case of distant or international applicants, interested parties can be emailed time bounded BDM/SI questions with the expectation that responses will be gauged against the successful grant application. Candidates showing promise can be contacted via video conference for a 'second' round of questioning prior to investing in flying in individuals for a final interview.

VII. CONCLUSIONS/RECOMMENDATIONS

Holders of research grants appreciate that they must secure the services of knowledgeable, capable, turnkey team members as a matter of successfully achieving research program objectives. Rather than proceeding in the typical extemporized manner regularly and broadly employed by those in hiring positions, the use of a few well chosen, sequenced, empirically validated approaches to personnel assessment can boost the probabilities of attracting and retaining high performance individuals. Adopting a disciplined, structured to the selection of personnel will ensure that the university researcher is obtaining maximal benefit from finite research funds.

Structured interviews with multi screening components represent a preferred way to identify and select successful job candidates. Additional steps within the selection process point to higher predictive validity but must be tempered against the hiring costs/risks involved (term of employment, level of responsibility, dollars committed).

The structured, multi-step BDM/SI approach delivers an effective means of assessing applicants. Utilizing grant application questions in a BDM or SI format permits applicants to consider the same questions and issues that will become part of their job responsibilities. Successful job applicants, soon to be part of the research team, should be capable of providing succinct responses to similar questions, as found in a grant application.

The approach suggested within the case study employs empirically validated selection methods to identify and hire the best candidate and does so by building on grant application questions along with researcher developed/provided answers. The structured interview becomes an oral and written examination of a candidate's ability to contribute to the goals of the research program. As a reflection of the situational specificity hypothesis, it should be recognized that different questions and approaches should be used for both graduate students versus post-doctoral fellows and local versus international candidates. The selection approaches presented in this paper capitalize on the enterprise, energy, and work that the researcher invested in the grant application. Adoption and adaptation of the procedures and practices will assist researchers in navigating away from both Type 1 and Type 2 errors.

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Problem & Project Based Learning: Preparing Students from developing Countries - A comparative Analysis -

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***Abstract*—Students from developing countries often face enormous difficulties to successfully complete their studies in western countries. Besides the cultural shock of getting used to the new environment the style of learning and teaching in their home country seems to be a major obstacle for a fast and successful integration into European learning environment. Most of them are coming from a culture with high power distance between levels, such as parents and children, teachers and students, employers and employees [1]. In this view, the teacher is always considered the major knowledge provider with the students as passive recipients [2]. At European universities they are expected to be responsible for their own learning process. Especially in a Problem-Based Learning environment where students are supposed to think critically and analytically and learn to be self-directed under the process [3], which is not part of their educational culture so far.**

This paper reveals the opportunities of cooperation between Universities in Germany, Uganda and Vietnam to overcome these problems in preparing students in their home Universities for studying abroad and preparing teachers in setting up a common intercultural understanding and initiating a change process from an omniscient teacher to a facilitator observing and directing a learning process.

Keywords—PBL, Project Based Learning, Power Distance, International Cooperation;

I. Introduction

Universities in Germany more and more offer at least some of their Masters programmes taught in English to offer their graduates a better foundation for an international professional career and to be more attractive to international students. As there are no study fees in German Universities, they are facing a fast increasing number of students from developing or newly industrialised countries.

Students coming from these countries are used to a classical teaching style and to a classical type of exams checking what they learned by heart and can reproduce exactly as the lecturer presented during lectures.

About a decade ago, Heilbronn University implemented some modules taught in Problem and Project Based Learning in its Bachelors program of “Software Engineering”. Additionally, since 2008, the same approach was introduced in its Masters program in “Software Engineering and Management”. Experience from these two programs indicates that foreign students have huge problems in adapting to this teaching and learning style. Developing their own solutions and defending them against critical questions of the lecturer in many cases is asking too much from them.

In 2009 Vietnamese German University had its first intakes as a new model University in Vietnam and offered the opportunity to apply a new approach of teaching in a newly industrialized country. In 2013, Mbarara University of Science and Technology started its new “Faculty of Applied Science and Technology (FAST)” which as well opens the possibility to implement and adapt some new teaching approaches in a developing country like Uganda.

II. Initial Situation

Heilbronn University is a university of applied sciences, which attracts its students out of a circle of 80 kilometers around the city of Heilbronn. The University has a strong link to industry situated in the area like Audi, Bosch, Daimler, Porsche or SAP and many small and medium sized companies. Its goal is to educate graduates who are ready to work in these industries.

For about 10 years, some of the Bachelors programs started to partially shift to problem and project based learning because they were facing problems with a lower level of competencies with students entering the univeristy [5]. One of the first steps was to include industry-based projects to different subjects [6].

During the same period Heilbronn faces an increasing number of students coming from developing countries. Besides language challenges they are facing cultural problems in the beginning of their stay. During the first year of the Bachelors program, many of them wish they could go back to their home countries. . But the most important issue is that lecturers expect students to show responsibility for their learning outcome in a certain way and to develop their own ideas and solutions on a given problem using the provided theoretical background. But most of the foreign students neither are able to do this transfer from theory to practical application nor are they confident to defend their solution. Most of them try to hide in teams during the first year and hope that the lecturer won't discover their weak points. This leads to dissociation of the students from the rest of their class. Students don't want to have team members who practice social loafing. So the vicious circle becomes closer and closer.

Consequently, we have two categories of students; those who overcome their weak points, associate with German students, and suddenly become high performers because they very often have a very good theoretical background; their formerly passive treasure of knowledge. In most cases, after having successfully graduated, they stay in Germany, get good jobs and only come to their home countries as "rich European" visitors. Thus, their countries lose productive manpower, which is essential for sustainable development.

On the other hand, we have those who only associate with students from their home country or region, keep complaining about hard life in Germany and don't dare to go back to their home country admitting that they have failed. In many cases these students are running into financial trouble or stay illegally because their visa expired and they have no justification for visa extension. But in any way they are lost for their home countries as well.

III. The Opportunities

Concerning our foreign students, we strongly believe that they need to be oriented before and after arriving in Germany. In 2009, we got the first opportunity to run a Masters program at a German Vietnamese University (GVU) in Ho Chi Minh City to get some experience in teaching in a newly industrialized country. In 2013, Mbarara University of Science and Technology (MUST) started its initiative of a Faculty of Applied Science and Technology (FAST), which aims to utilize problem-based teaching and learning. This was after having realized that many of MUST graduates are facing problems to find jobs, while those who get jobs find difficulties to apply the knowledge gained from the University to real life situations.

A. Setting up a model University in Vietnam

Vietnamese government started an initiative of setting up four model universities following the education standards of four different industrialized countries. One of them is the Vietnamese German University in Ho Chi Minh City [4]. Each German University involved in the initiative provides a study program. The short-term goal is to educate Vietnamese students to get a German Degree in Vietnam. Mid-term goal is to train Vietnamese staff to take over teaching but in the style of a German university. German staff members are still involved and a German Degree is still provided. Long-term goal is to completely hand over the model University to Vietnamese staff. VGU will provide their own degrees but in a strong partnership to the originally providing Universities in Germany, giving a chance to the top-level students to get a scholarship and come to Germany and get a double degree from the Vietnamese and the German Universities.

A so-called "flying faculty" is travels from Germany to Vietnam to provide the courses in blocked units of two and a half weeks. The Masters program is a part-time course and all our students are working in software companies, most of them in offshore companies for clients in Europe, Japan, South Korea or the US.

The students get the background literature for each unit about two weeks in advance. They set up teams and prepare their initial assignment just before the lecturers fly in. We get enough time for workshops on Saturdays and Sundays for 6 hours per day as well as three evenings for 3 hours in week days. In the first week the students get a small assignment where they can easily apply the theory they have been reading about and present their results to their classmates. During the second week they get a more complex project to work on. The third weekend they present the result of their project work and explain the underlying theory.

That's more or less the identical approach like we do it in the Masters course in Heilbronn, but here the different subjects are worked out over the whole period of one semester. In Heilbronn we have students in the Masters class from all over the world while in Vietnam we have a homogenous group of Vietnamese students. Another advantage of the Vietnamese students is that most of them have work experience of 1 up to 3 years, which is very helpful when it comes to self-directed problem based learning.

The interesting fact to observe is that the Vietnamese students even if they are not used to this style of teaching and learning, perform well while foreign students in Heilbronn are still facing difficulties in getting used to the approach.

One major reason seems to be the difficulties in getting used to the social and cultural environment in Germany, since in Heilbronn, the students have to deal with a very diverse and intercultural structure of class.

The best performing 20% of the Vietnamese students actually get a scholarship to work on their thesis project in Germany. Again we can observe the Vietnamese students coming to Germany having their issues in getting used to country, culture and classmates. But they already have the advantage of being prepared to the teaching style.

Finally we can conclude from our two focus groups:

Table I. Comparing the focus groups

	Heilbronn Masters Students	Vietnamese Masters Students
Getting used to culture in the beginning of their studies	Difficult	n.a.
Getting used to teaching style	Facing some difficulties	Easier because they are still in their familiar environment
Getting used to culture in the end of their studies	n.a.	Difficult
Ability to perform their	Medium – high (depending on	Medium – high (depending on work

thesis self-directed	work experience)	experience)
Request to stay in Germany for getting more "German" work experience	High	Medium - low
German language skills after one year	medium	Low - nonexistent
Opportunity of getting a job in Germany	Medium to high depending on German language skills	Low because of missing language skills

Students already having work experience have a strong advantage in studying in a PBL (Problem Based Learning) way. Students learning the PBL way in their home country, in a well known environment and culture adapt much faster and easier to the learning situation outside their countries and they are able to successfully pass a short-term study visit of one semester. This gives another advantage that these students normally return to their home countries to become a supporter of their native industry. Nevertheless they have built a strong relationship to Germany and German industries.

Students starting their studies in Germany from scratch need some special support like a foundation semester where they get used to working/teaching style, culture and environment. They build a very strong relationship to Germany. Very often they permanently stay in the country.

B. *Establishing a Faculty of Applied Sciences in Uganda*

Mbarara University of Science and Technology (MUST) is the second Uganda's public University established in 1989 with a mission of providing "quality and relevant education at national and international level with particular emphasis on science and technology and its application to community development."Traditionally, the teaching and learning approach at MUST has been that of lecturer–centered. Students expect to learn everything from the lecturers. They perceive lecturers as all-knowing. Many of the lecturers also were taught using the same approach. Therefore, they lack problem-based teaching skills and industrial experience that would help them envision the practicability of what they teach. MUST has some few lecturers that have had opportunities to be exposed to PBL in industrialized countries. However, these lecturers often face challenges of student resistance when they try to introduce the same approach in MUST. Students normally report them to University administration as bad lecturers; claim lecturers are paid to teach them; refuse to be interactive in class as well as refusing to do the projects assigned to them. Those who try to do their projects often copy and paste contents from the internet and illegally claim ownership of the content.

To avoid bad labels and risk of losing their jobs, such lecturers often refrain from utilizing PBL. The option is to use the dominant lecturer-centered approach that makes it difficult for students to relate concepts to real field/work experiences. Consequently, many MUST graduates struggle to apply their theoretical knowledge in addressing practical situations at their work places. Others cannot be absorbed in the current job-market, which is skills-oriented. Other challenges include: the curricula that is short of contents that would spur students problem solving and creative skills; lack of strategic collaborations with industries that would provide placements for student and staff. It is also documents that some staff have struggled or failed to complete their studies from industrialized countries due to differences in teaching methods and cultures.

MUST is currently establishing a new Faculty of Applied Science and Technology (FAST) with a mission of providing quality, specialized and relevant education and research that contribute to local, regional and national development. Given the practical nature of the programs (mainly engineering and applied sciences) that will be running in the FAST, FAST is currently collaborating with faculty from Heilbronn University Germany to utilize problem based teaching and learning. This includes developing new curricula that emphasize students' engagement; involving industry in curricula design to better address their needs; establishing strategic partnerships with industry to get opportunities for student internships supervised by MUST staff; offering internships for staff members to get a better understanding of industrial needs and be able to prepare students meet the identified needs; preparing students for short-term and/or long-term exchange programs with Europe and other industrialized continents. Our preliminary analysis indicate that problem based learning can work in the FAST, and many staff are excited about it. Rolling out the approach to the entire University will no doubt scale up the impact and result in producing hands-on graduates that truly reflect a University of Science and Technology that MUST is.

IV. CONCLUSION

Preparing students and graduates for studying in Universities or working in industry of industrialized countries is an essential task for developing or newly industrialized countries to get their labor on a competitive level. Universities in industrialized countries can offer supportive training courses for incoming students. In many cases it is not sufficient to fully integrate these students in the short period of time available—maximum one semester (including language courses).

Changing the way of teaching in the target countries seems to be essential. The first approaches of implementing these new ways of teaching by bringing in lecturers from industrialized countries can only be a short-term solution. Transferring the European way of teaching in training lecturers from the target countries to teach in the same way might not be successful. Students are eager to learn in a new way from European lecturers but they are not necessarily willing to accept the same behavior from a lecturer originally coming from their countries. Implementing new ways of teaching does not mean to copy some models from industrialized countries. These models need to be adapted to cultural environment in the countries with respect to determining factors like power distance or other cultural settings. And on a long-term, lecturers and students need to initiate a change process in their learning culture, which then may be transferred to the organizational behavior in industry as well.

The two approaches we are actually trying to follow are entirely different. The Vietnam approach is demanding a huge amount of money from German (app. 3 million € p.a.) and Vietnamese (200 million USD investment) government. So we might not be able to transfer. The Ugandan approach is much smaller and can be done with own resources except some few initial visits from German lecturers to teach the new way of teaching. And there is already coming up some demand from other universities in east Africa. The jungle drums are working brilliant;-)

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Implementing Reflective Writing in a Problem-Based Learning Civil Engineering Programme

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***Abstract* – Some issues of current concern in engineering education are described. The theory, rationale and implementation of reflective practice in educational settings are briefly reviewed. The use of reflective writing in the University of Limerick's (UL) Problem-Based Learning (PBL) Civil Engineering programme is described.**

The habit of 'reflection' is embedded in the context of a full scale design-and-construct problem in year two of the programme. Student reflections were captured in learning logs over two successive years. Aids to prepare students for reflective writing are described. Outcomes before and after implementation of the more recent aids are examined. Analyses of these data are presented and discussed. The paper concludes with some proposals for further development.

Key Words – Reflective Practice, Problem Based Learning, Civil Engineering.

I. Introduction

Learning outcomes documented for professional engineering programmes internationally agree that developing autonomous lifelong learners is essential [1 p. 15, 2 p. 3]. Stakeholders worldwide discern an urgent need for reform to achieve the desired outcomes. Fundamental problems with graduate capability have been identified as long ago as 1977 [3]. Accreditation bodies, industry and educational researchers all agree that traditional lecture based delivery systems in isolated subject streams are not achieving the desired outcomes [4, 5]. A variety of responses to this crisis are evident often including the adoption of various learning-by-doing approaches e.g. Problem Based Learning. Donald Schon highlighted the processes that led to the divergence between the concerns of the academy and professional practitioners [6]. He describes 'reflection in action', as fundamental to the world of practice but largely absent from the traditional academy.

The Civil Engineering program at The University of Limerick (Civil @ UL) was built *ab initio* around a PBL methodology. Therefore the work reported here takes place in a PBL context. For an account of the overall strategy see [7]. This paper focuses on one element only of this strategy: reflective writing. The reflections are however, strongly conditioned by the PBL context and the study will, therefore, be of interest to both practitioners and researchers in PBL.

II. Developing Life-Long Learners

Reflective practice in professional education is now well established, particularly in health and teacher education programmes. But all professions now agree that the development of autonomous, and therefore reflective lifelong learning is central to modern professional formation. Research supports the contention that metacognition or self-awareness of one's thinking and learning processes [8] is a necessary aspect of this orientation.

"Reflection can be described as a mindful, metacognitively controlled activity. Mindfulness in learning refers to attentive, volitional and effortful dealing with subject matter ... Empirical findings confirm the relevance of reflection to enhance deep processing [9] *and understanding."*[10]

Metacognition, or reflection on one's learning process, is fundamental to facilitate deep (as opposed to surface) learning [8 p. 7]. Reflective learning logs or diaries are commonly used in health-related and teacher education programmes to develop a reflective orientation in students. Their use in other settings including engineering is rare.

The other two programme components necessary for deep learning are conditionalised knowledge and communities of inquiry (*ibid*). *Conditionalised knowledge* is "knowledge that specifies the contexts in which it is useful" (*ibid*, p.6). PBL is a commonly-used strategy to facilitate such knowledge (*ibid*). *Communities of inquiry* (COIs), also referred to as communities of practice, involve three modes of presence: cognitive, social and teaching presence [11]. Cognitive presence refers to the learner's ability to progress from the initial stage of inquiry to resolution of the problem (*ibid*). The indicators of cognitive presence (which parallel the PBL process) are:

- Triggering event (typically indicated by a sense of puzzlement and recognition that a problem needs to be solved)
- Exploration (indicated by information exchange and discussion about the nature of the problem)
- Integration (indicated by learners connecting ideas and applying various theories to the problem)
- Resolution (indicated by learners applying new ideas to solve the problem)

The other types of presence needed for a community of inquiry – social and teaching – will be examined in greater detail in future work.

III. REFLECTIVE WRITING IN CIVIL @ UL

Reflective writing was introduced in autumn 2009 when the first cohort of students were entering second year. This decision was influenced by Cowan's work [12] where implementation of reflective writing in a variety of programmes was shown to be measurably effective. Teaching tools, based on established models for reflection [12, 13] have been developed to support the students in their reflective writing.

While reflective writing occurs throughout the programme, this article addresses the output from the 'Steel and Timber Design' module in year two and a following module in 'Hydrology and Water Engineering'. The reflections were assessed using a grading rubric developed from Driscoll's (2007) model. Reflections submitted before and immediately after a reflective writing workshop are compared. In response to the very uneven quality of reflections initially submitted, these tools were developed further. Table I summarises the development and use of these tools. A description of the stages follows the table.

Table I: Preparation for Reflective Writing: Development of Methods

Year	Cohort	Stage	Preparation Method
'09-'10	1	A	1 page guide presented to class
		B	As A + feedback on exemplar student reflections
'10-'11	2	C	As B + exemplar staff reflections
		D	As C + Driscoll's model + Univ. Portsmouth guide + Active reflective writing session + Peer review of reflection + Tutors' model reflection and review
		E	As D + Student assessment of tutors' reflection, using Driscoll's model

A. Stage A:

A one-page guide, which was presented in class, enunciated Cowan's definition of reflective learning:

Learners are reflecting when they analyse or evaluate personal experiences that have a bearing on their learning and attempt to generalise from that thinking. They do this so that in the future they will be better informed or more skilful or more effective than they have been in the past [12]**.**

There followed some suggestive questions to provoke reflection and a specific direction to go beyond narration.

B. Stage B:

Feedback on anonymised extracts from the students' own reflections was provided. Examples of superficial narrative and deep reflection were presented by way of contrast. The students were then asked to confer in groups to assess further sample reflections in the light of the definition and the examples just given. The results suggested that many of the class did not grasp the distinction between narration and reflection.

C. Stage C:

In addition to the Stage B guidance, the first author shared an extract from a reflective assignment for a staff development programme and another on his experience of teaching the module in question. Demonstrating authenticity to students in regard to reflection is important. Encouraging students to reflect while neglecting to reflect oneself is inconsistent. (The students were amused to hear that a staff member was also subject to reflective writing assignments, electronic submissions and deadlines.)

D. Stage D:

Following a consultation with the Centre for Teaching and Learning at UL we arranged a reflective writing workshop. Driscoll's model for reflection was chosen for its clarity and simplicity (compactly summarised as ***What? So what? Now what?*** [13]). A short reflective writing guide from the University of Portsmouth was also presented. Students and staff who attended the workshop were then invited to prepare a brief reflection on one significant experience from the module. They were then invited (not compelled) to share this with a peer for review. The peer was required to provide feedback using Driscoll's framework. The tutor peer pairs were invited to share the reflections and peer reviews with the class.

E. Stage E:

A further short workshop was arranged during a following module, 'Hydrology and Water Engineering'. One tutor's reflection, prepared as part of diploma coursework, was distributed. The students were asked to read this and review it in groups using Driscoll's framework. As only half the class attended, the opportunity was taken to compare grades of those who attended the workshop with those who did not.

IV. RESULTS FOR STAGES A & B: COHORT 1, YEAR 2

Reflections throughout this year demonstrated a wide variation in quality. Some were narratives with limited reflective content, e.g.:

"I learned how to design a beam"

"I learned about simple v rigid construction"

Others were deeply engaged reflective pieces demonstrating significant metacognitive awareness, e.g.:

"During this module there were a number of things that finally made sense, things now had more of a purpose. I also noticed I take longer to understand some topics and have to go through some topics at a slower pace myself."

"This has made me see that as Engineer's we need to maybe slow down, stop racing into the calc's, spend a little more time weighing up the various scenarios."

"The enthusiasm of one or two in a team can push things on too fast before all the angles of the current issue are exhausted."

Some students used guidance documents we provided as a rigid checklist. Many produced a diary without a reflective examination of experiences. Some produced reflections with themes and phrases closely aligned with the exemplar guidance. Some students included feedback on the programme mixed with the reflection. We acknowledged the usefulness of the feedback, even though it was not the goal of the reflective exercise.

V. Results for Stages C & D: Cohort 2, Year 2

The sample size for Stage C was 30 and for stage D was 27. There was an increase in A2 and B1 grades, with a quarter of the class improving by at least a grade. The average percentage mark improved from 54% to 58.4% (see Fig 1).

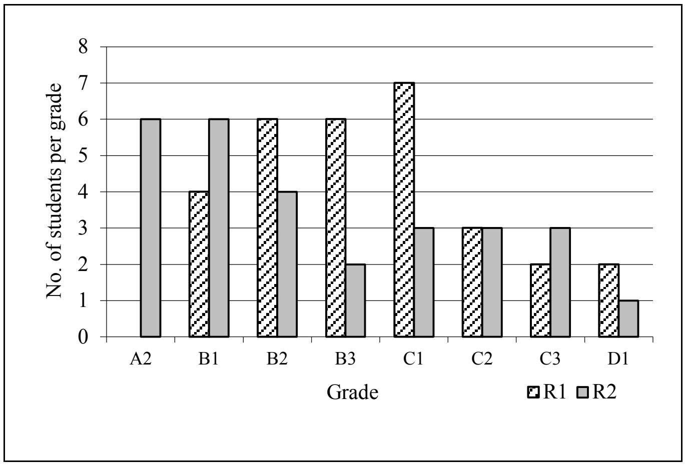

Fig. 1. Reflection Grades

VI. Comparison of Grades for Stage E: Cohort 2, Year 2

Here we are comparing grades for those who attended a further reflective writing workshop in a follow-on module in 'Hydrology and Water Engineering' with those who did not. The mean percentage mark for those who attended was 56% compared to 49% for those who did not attend.

VII. Tutors' Reflections

We find as educators that reading students' reflections give us a deep insight into the real struggles, frustrations and successes of our students. Their developing insights, struggles and victories are palpable on the page. The diversity of experience and talent among our students becomes visible. This has a strong positive motivational impact on us. There is a deepening of awareness of the students as persons. In addition, feedback on various aspects of the programme surfaces naturally. This feedback is useful, though not always reflective in character.

VIII. Discussion

Our experience indicates that providing guidance in reflective writing is effective. However persistence is required. We are working to further develop our resources and practice. In future we will not use reflective pieces generated by staff as students seemed quite reluctant to critique tutors' work. The weaker reflections do not engage with the students' own experiences in a reflective manner. The reasons for this will vary but may include prior unreflective learning-by-rote conditioning, perceived insufficient marks to justify the effort, insufficient skills development in reflective writing, and/or too many reflective writing assignments.

IX. Three Challenging Questions

Are we as tutors trustworthy?

Authentic reflection requires a degree of self-revelation and therefore trust in the tutor. Ghaye illustrates the ethical dilemmas and potential negative impact of compulsory reflective writing [14].

Should reflective writing be assessed?

Cowan encountered similar dilemmas to Ghaye and concluded that students' reflective pieces should not be assessed, though he did give feedback which was grounded in a Rogerian praxis of 'unqualified positive regard' [12]. Slattery found that more students maintained reflective journals when they were required to do so, than when reflection was voluntary and did not count towards the final grade.

How can we ensure authenticity?

Student teachers can invent classroom episodes to satisfy the requirement for reflective writing. The first author has himself encountered this phenomenon among postgraduate students in other disciplines. It is fair to say that learning activities in CIVIL@UL do not involve the ongoing affective personal dilemmas that characterise the health and education professions. Therefore the issues noted above may not be quite as intensely felt. We cannot, however, assume they do not exist and we must remain alert and critical in our practice.

X. Conclusions

Providing guidance in reflective writing improves the quality of students' reflective writing. Teaching and preparing authentic reflective writing takes time. Staff engagement and motivation is enhanced. Feedback on the programme itself often occurs as an ancillary benefit.

XI. Future Developments

We are preparing exemplar reflective pieces from various disciplines for use in future workshops. Students will critique and assess these pieces individually using the CIVIL @ UL grading rubric and then discuss their results in groups. These will highlight evidence of cognitive and social presence [15] thereby reinforcing the rationale for reflective writing and enhancing engagement.

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Design and Validation of Leadership Education Integrating Simulation and Project Based Learning

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***Abstract*— All engineering students need to develop their important skills of leadership in project management. Many students have never been leaders in their social and school lives. A leading role is unimaginable to them, and hence they cannot imagine how to achieve it. Therefore, as our project management education we employ training that utilizes simulation in order for students to have many simulated experiences, allowing the students to develop their leadership skills in Project Based Learning(PBL).**

The first step is for graduate students to gain knowledge in the leadership arena. Then, they utilize simulation to experience leadership actions many times. Simulation provides a safe environment in which they can try out many different approaches in taking leadership in various situations.

In the next step students as a team utilize PBL so that the above simulated experiences can help them to actually take leadership. Students can apply trained leadership to actual projects. It is highly effective to apply conscious leadership to a project aimed at a specific goal in limited circumstances. This education repeats both of the steps above, raising leadership abilities in an upward spiral.

In terms of students' evaluation of leadership education in project management, 360-degree assessments were carried out by teachers, senior and junior students before and after the course, and we compare their assessments thoroughly. As a result, we are assured that students not only gained knowledge but also raised leadership abilities in their actions after this education.

Six months after the time of leadership education employing simulated experiences and PBL, we conducted follow-up interviews on its effects. We recognize the cyclic period that students apply simulated experiences to PBL, and that they seek different approaches in simulation for solving problems found in reality. We made sure that this cycle of simulator and PBL can produce effective leadership actions.

Keywords*— *Project Management, Leadership, Simulation, Project-Based Learning, Reflection

I. INTRODUCTION

A project is defined in Project Management Body of Knowledge（PMBOK）[1]; a series of fixed-term works in order to make a unique product, a service or a result. Research has been conducted on situational leadership and leaders' roles in projects previously [2]-[4]. However, since each project is unique, it is hard to specify one specific leadership style that can lead a particular project to success. Hence, it is meaningful to pursue approaches of leadership which are applicable to any projects.

All engineering students need to develop their important skills of leadership in project management. Many students have never been leaders in their social and school lives. A leading role is unimaginable to them, and hence they cannot even imagine actual manners to take leadership. Therefore, as our project management education we employ training that utilizes simulation in order for students to have many simulated experiences, allowing the students to develop their leadership skills in Project Based Learning(PBL).

II. LEADERSHIP EDUCATION THAT INTEGRATES SIMULATION AND PBL

A. Education that Utilizes Simulation

Students who are lacking of experiences have huge gaps between knowledge and action. As a consequence, it is impossible for them to immediately turn knowledge into action. Therefore, we utilize simulation as a means to bridge these gaps.

In other words, simulation allows students to effectively accumulate many simulated experiences. The simulated experiences that students acquire through repetitive practices can provide a smooth bridge to reality [5].

B. Application of Simulated Experiences to PBL

Any project has no precedent, in which case a creative solution is necessary. Members of such a project are required to have creativity and high motivation. Therefore, it is rational to facilitate an organizational operation structure, which allows leadership to be generated and functioning for project activities. All the characteristics of such an organizational operation structure are: a goal setting based on mission, outcome assessment, non-finite rules on actions, and rich communication between members [6].

By utilizing simulation, it is effective to apply simulated experiences as a leader to PBL,

III. Definition of Leadership

In this research paper, leadership is defined as an ability to grasp emotion of team members accurately, to empathize with them, and to appropriately develop human relationships. In addition, leadership is not an ability bestowed upon to a special person, but rather an ability for everyone to exhibit and develop.

IV. Educational Objecttive

The composition of study / educational objectives and a lesson are shown below.
Study / educational objectives:
- To understand the systematic knowledge needed when implementing project activities.
- To practice skills and leadership within the technical areas of science and engineering.
- To understand one's own skills and to set up a behavioral objective.

The class consists of group exercises, such as a leadership exercise which utilizes simulation software, and a lecture. Parallel to this, work linking the lesson to PBL is implemented.

V. Style of Teaching and Learning

Education and learning styles are shown in Table I. The level of study is gradually set up in order of:

1. knowledge
2. consciousness
3. action
4. mastery

Leadership education course consists of two stages in project management. The first step is for graduate students to gain knowledge in the leadership arena by lecture. Then, they utilize simulation to experience leadership actions many times. Simulation provides a safe environment in which they can try out many different approaches in taking leadership in various situations. A simulation exercise has the effect of raising awareness of daily improvement and the necessity for new action as a result of self-reflection, all of which stem from the various virtual experiences.

In the next step students as a team utilize PBL so that the above simulated experiences can help them to actually take leadership. Students can apply trained leadership to actual projects, and their leadership skills are additionally raised. It is highly effective to apply conscious leadership to a project aimed at a specific goal in limited circumstances. This education repeats both of the steps above, raising leadership abilities in an upward spiral. Based on this plan, the flow of study and education in Figure1 was designed.

Table I . Learning Styles Combined for Leadership Education

		Lecture	Simulator	Project based learning
Merits		Deep knowledge	Many simulated experiences	Real experience
Demerits		Passive learning	Virtual	Not have a second chance
Level	1.Know	xxx	x	
	2.Conceive	xx	xxx	xx
	3.Act		xx	xx
	4.Master		xx	xxx

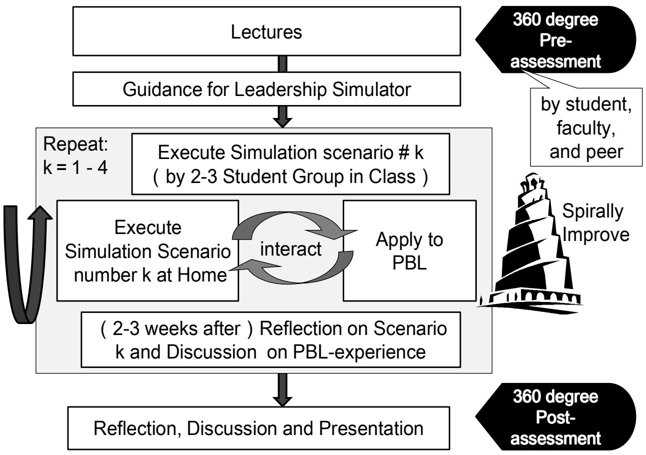

Fig. 1. Architecture of Leadership Education

The Virtual Leader (Japanese version) of U.S. Simulearn was used for the simulator [7].
The following scenario was set up for the students:
Scenario 1 – A meeting with a junior.
Scenario 2 – A meeting between two juniors who hold conflicting opinions.
Scenario 3 - A meeting with a teacher, a senior, and a junior.
Scenario 4 - A meeting with superiors.

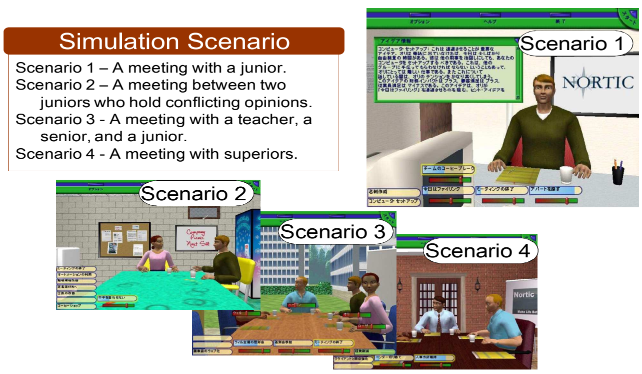

Fig. 2. Leadership Simulation Scenario

VI. ASSESSMENT OF LEARNING OUTCOME

Regarding assessment of leadership outcomes, we conducted 360-degree assessments and a follow-up interview six months after the time of course.

A. *360-Degree Assessment*

Regarding leadership actions of the students before and after the leadership education course, we conducted 360-degree assessments on a 5-point scale to professors, senior, peer and junior students with the questionnaire of Table Ⅱ. As a result of the course, scores are raised in all 12 items (Fig. 3). Items 5, 9, and 10 saw especially significant increases. The evaluation of items 5 and 9 had been poor, when they were assessed in a graduate school research seminar which included simulated experiences, but not in a project [5]. Application to a project seemed to develop students' problem solution and planning abilities. Also, the students who himself took the course showed higher score raise rate than the other evaluators (Fig. 4).

Table II. Assessment Items

#	items	
1	I can devise my work to contribute to an activity in a project.	work
2	I can understand specific situational requirements and encourage project members to achieve their goals.	
3	I can contribute to a project and achieve results through work.	
4	I can share knowledge and technology with a project member positively, and can strengthen a mutual relationship.	power
5	I can discern the cause of a problem, acquire pertinent information, and determine a solution.	
6	I can carry out activities for the smooth progress of a project.	
7	I can coordinate socially relevant research tasks with and plant the seeds for scientific innovation.	idea
8	I can propose an idea with confidence in a timely manner.	
9	I can create a plan foreseeing short and long-term research results.	
10	I can manage my and others' ability to cope with high pressure situations or rapidly changing environmental conditions.	tension
11	I can engage a project member in conversation, listen attentively and positively, and show sympathy.	
12	I can raise motivation by managing a project member's level of stress.	

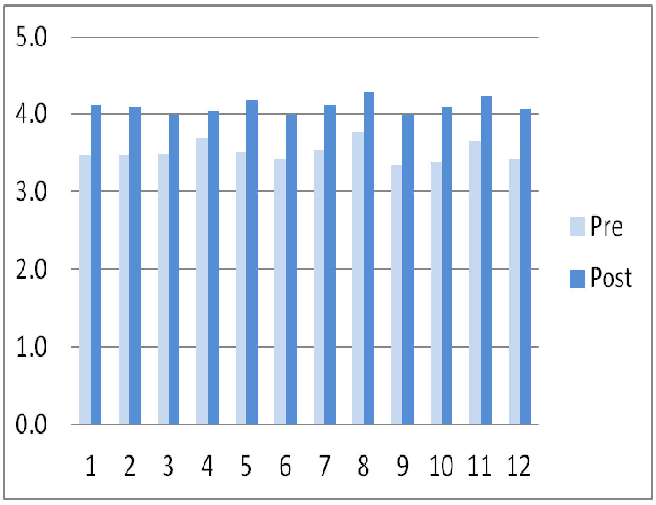

Fig. 3. Improvement of Student Behavior for every item in Table II

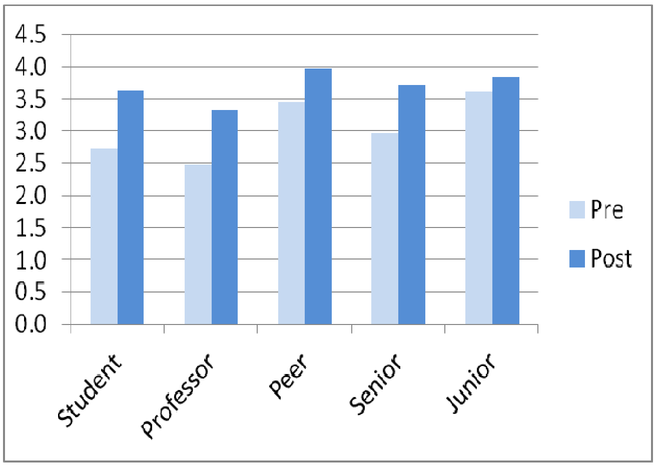

Fig. 4. Improvement of Student Behavior by 360 degree assessment in Table II

B. *Follow-up interview*

Six months after the time of leadership education employing simulated experiences and PBL, we conducted follow-up interviews on its effects. We recognize the cyclic period that students apply simulated experiences to PBL, and that they seek different approaches in simulation for solving problems found in reality. We made sure that this cycle of simulator and PBL can produce effective leadership actions.

Table III . Student feedback comment

#	Student feedback comment
1	I came to understand people's emotions in a project. For example, when a person who often had stated his opinions responded with an authoritative tone toward a comment of a person who usually had not stated his opinion, I felt that this commentator became deflated and discouraged.
2	It is effective to apply simulated experiences to a project. Everyone has to work together to one goal, and therefore, each must positively give opinions, and each has many chances to take leadership. With simulation I came to think of how to run a project well.
3	When I had been a team leader in a project, I had always cared about moods of the team. With simulation I understood that I could not lead a project to success, if I only cared about these moods. I understood that the strong and powerful attitude and the tension it generated were sometimes important as well.
4	Since a project involves students who study different disciplines, I became aware of the difference of knowledge and the degree of understanding between project student members. Therefore, when I talked about the arena that other members are not familiar with, I always made sure they understood. In this manner, the mutual understandings between members were enhanced.
5	With simulation training, I realized that a project could not be accomplished, if only I talked about my opinion. It was important to have all the team members' opinions.
6	I tried different approaches in simulation for solving problems found in a project. Then I applied these approaches to the real project. Until the project was completed, I repeated this cycle.
7	I had not been able to accomplish the cycle of PDCA (Plan, Do, Check, Act) previously. However, after trying simulation, my skills on running a project as a whole are raised, and I was able to lead a project to success.

VII. CONCLUSION

We introduced leadership education which integrating simulation and PBL.

The first step is for graduate students to gain knowledge in the leadership arena. Then, they utilize simulation to experience leadership actions many times.

In the next step students as a team utilize PBL so that the above simulated experiences can help them to actually take leadership. Students can apply trained leadership to actual projects, and their leadership skills are additionally raised.

We validated that this cycle of simulator and PBL can produce effective leadership actions.

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Facilitating Transformative Interdisciplinary Collaborative Projects: The IMPACT (Interdisciplinary, Meaningful, Practice, Applied, Community, Transformative) Project

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***Abstract*—Institutional and departmental boundaries often sequester undergraduate and graduate students into specific academic silos, hindering knowledge mobilization for its practical implementation, and defining problems in disciplinary rather than practice terms. To create learning among students from diverse fields, we designed and implemented a model for interdisciplinary collaborative projects involving instructors, undergraduate, and graduate students. The aim of the project was to improve the life a person with a disability living in the community by designing a product that addressed a unique need. In the process, over 1200 students (Engineering, Biology, Rehabilitation Science) participated in a series of collaborative lectures and tutorial activities, including critical feedback sessions. For the first-year Engineering students, this mandatory project was part of their professional and practice training. The project is spread across a seven-week arc during which students iterate on their work by interacting with the client and experts in lecture and participate in studio work on a weekly basis, where the members of the university and local community engage individual teams of engineers. For Biology undergraduate and graduate students, the interdisciplinary project provided an opportunity to apply their critical thinking skills regarding the biological basis of rheumatoid arthritis and its treatment to provide constructive feedback for the design of the mobility device. For the upper year graduate students in the Occupational Therapy (M.Sc., Rehabilitation Science program) who participated, this project provided an opportunity to apply their clinical skills and interact with future engineers who design such products.**

In this paper, we will highlight the IMPACT project model for linking expertise and disseminating insights and resources in any discipline with the goal of creating meaningful change in the local community. Specifically, our interdisciplinary model/template successfully solved a real-life challenge faced by a client, with severe rheumatoid arthritis. The designing of the actual mobility device not only engaged the learning of students across disciplines, but also transformed the life of the client as she indicated "you may actually not be aware of how profound a change you've made in my daily life, I no longer have to plan, strategize, or organize my activities around optimum times to fuel the car".

Keywords—Experiential learning, Interdisciplinarity, Community engagement, Engineering design, Large course, First-year engineering;

I. INTRODUCTION

The current employment landscape is evolving. No longer can our graduates expect to earn a university degree and spend their entire career applying their disciplinary knowledge at work for a single firm or organization. Today's work environment is far more dynamic. Our graduates are likely to hold several jobs in their careers. The specific knowledge of their undergraduate education will see application in a relatively small number of our graduates. Recently, the Ontario Society of Professional Engineers published a study [1] that reports that only about 30% of our engineering graduates work in jobs that they report as engineering work.

The changes in the nature of the work, are in large part, being driven by changes in technology and its use in the workplace. Levy and Murnane [2] report that the automation and computerization technologies have significantly changed the work environment not only for low-paid and low-skilled employees, but also for highly educated professionals. The future for workers with higher education will fit into one or more of three categories: where human beings are required, complex communication, and unstructured problems. However, the nature of engineering suggests that the future will demand a greater degree of interdisciplinarity, creativity and communication to solve unstructured problems.

This paper describes a first-year engineering course, Engineering Profession and Practice, in which students work on a "real world" problem. The model introduced is called the IMPACT Project. To mimic that real world environment the project has elements of interdisciplinariness, experiential learning, community engagement, and self-directed learning.

II. PEDAGOGICAL THEORY

Our engineering education philosophy, with few exceptions, is predicated on the notion that engineering fundamentals are the primary domain of study for undergraduate engineering students. Engineering undergraduates study courses in mathematics, science, and engineering science with the occasional sprinkling of design, communication, and ethics. Given that engineering scientists are teachers of undergraduate engineering students, this decidedly reductionist point-of-view should come as no surprise.

In his seminal work [3] Schön suggests the practitioner's point-of-view is a radically different perspective from that of the reductionist educator. If the role of the engineer is merely to apply the labour of their undergraduate education to the problems of everyday practice, then the education would be wholly adequate. However, he points out that the problems facing practitioners, often daily, are not easily reduced, if at all, to the knowledge earned in any undergraduate education. Practitioners' problems have characteristics of open-endedness, ill-structure, ambiguity, incompleteness, uncertainty, uniqueness, and contradictions in requirements. The very nature of the practitioner's work often requires an answer to complex problems even when the requisite knowledge is available.

In this context, a constructivist epistemology helps explain how practitioners think. In what Schön termed, "knowledge-in-action", practitioners essentially learn from experience to solve these problems in a model following Kolb's description. Hence interdisciplinary practice is not as much as about applying formal knowledge from multiple domains to a single problem but integrating multiple perspectives, experiences, and opinions with that problem.

III. THE ENGINEERING PROFESSION AND PRACTICE COURSE

The Engineering Profession and Practice course is a mandatory course for all first-year engineering students. At McMaster University, the first year in engineering is common. Students choose their discipline at the end of the first year. It is a process that can be competitive for entry into some departments. Enrolment is typically between 800 and 1100 students. In the fall of the 2013, there were 941 students enrolled at the close of the course. To support this enrolment, the teaching staff in the fall of 2014 totalled 30 persons including the instructor, a part-time course coordinator, three full-time teaching assistants, and 25 part-time teaching assistants, both undergraduate and graduate students from the Faculty of Engineering.

The course covers a plethora of topics related to the engineering profession and its practice. The topics include design, communication, teamwork, sustainability, safety, the profession, and engineering ethics. The course runs over twelve and a half weeks in the fall of each year. Students have two hours of lecture per week plus a two-hour tutorial. Lectures are typically taught in three sections to accommodate the large class size. The 24 tutorial run throughout the week with up to 50 students in a tutorial.

In previous years, the course was run as a series of guest lectures, quizzes, and unrelated assignments. Feedback from students made it clear the course was very low on their studying priorities and they questioned its relevance. Students frequently rated the importance of the course as very low in comparison to their mathematics and science courses. With the introduction of the IMPACT Project, the course has since received strong reviews from students.

IV. THE IMPACT PROJECT

The IMPACT Project is an interdisciplinary, collaborative project aimed creating interdisciplinary learning experiences in a way that positively impacts both students and the local community in a meaningful and tangible way. This project is partly inspired by our President's vision, Forward with Integrity [4].

The Project is the result of collaboration of faculty members from the Faculty of Engineering (Dr. Robert Fleisig, Walter G. Booth School of Engineering Practice), Faculty of Science (Dr. Lovaye Kajiura, Department of Biology), and Faculty of Health Sciences (Dr. Brenda Vrkljan, School of Rehabilitation Science). To achieve a measure of interdisciplinary experiential learning, students from Biology and Rehabilitation Science participate in the first-year Profession and Practice course as experts and reviewers.

Bringing together diverse professions and disciplines in this way was a way to provide the students with an opportunity to:

1. learn to deal with opinions and perspectives that may contradict their own;
2. learn to listen to feedback and critically analyze it; and
3. improve their communication skills by having to explain and justify their original ideas to persons who do not share their educational background.

V. MS. SANDI MUGFORD

Experience has taught us that creating meaningful interdisciplinary learning experiences requires a carefully selected client, a unique project problem, and sufficient scaffolding of the process to ensure students receive enough direction without comprising their creativity or independence.

In the fall of 2013, our client was Ms. Sandi Mugford. As a member of the local community her only previous attachment to the university was occasional interactions in the classroom with Occupational Therapy students in the School of Rehabilitation Science. Her suitability as a client was her comfort in speaking to large classes, availability and personal charm. In addition, she came to us with a real problem that she genuinely believed could and should be addressed by engineers.

Fig. 1. Note the joint deformation of Ms Mugford resulting in issues with tasks requiring fine-motor movements.

After three meetings with her, we determined that the context for the problem she would present to the class was the intersection of her disability, rheumatoid arthritis, and one of her frequent tasks, fuelling her car, which was pivotal to her personal independence and mobility. In October 2013, she came to lecture and watched, with the students, a recorded video of herself fuelling her car at the gas station across the street from the gas station. A single frame from the video is shown in Fig. 1.

It was clear to the students, from the video and the lecture, the Ms. Mugford suffered considerably from the simple task of fuelling her car. Although Ford had already redesigned the fuel cap so that is became an integral part of the door covering the opening, the students identified four clear opportunities for designing a device to help the students:

1. lifting of the nozzle and hose;
2. actuating the fuel flow by pulling the trigger on the nozzle;
3. depressing buttons on the keypad; and
4. inserting and removing her credit card.

It was up to the students to determine which problem or problems they were to tackle. They were required to deliver a functional prototype at the end of the project, one that Ms. Mugford could use on a daily basis, should she wish to. In addition, the budget was to be minimal and shop facilities were generally not available. The students were then led through a series of tutorials in which they had to deliver on a small assignment by the end of the tutorial such that would receive written feedback from the teaching assistant at the beginning of the next tutorial. All prototype fabrication was done outside of lecture and tutorial time.

Fig. 2. Student discussion during the interdisciplinary design review.

In successive weeks the students followed a conventional engineering design process, beginning with team formation leading to problem framing, conceptual design (sketching), prototype fabrication, verification, validation, and finally communication. The interdisciplinary aspect of the project occurred in design reviews with Biology and Rehabilitation Science students once an initial prototype was constructed. See Fig. 2.

VI. Outcomes

Fig. 3. Ms. Mugford with her new student designed and manufactured device.

Even with the large enrolment, all 199 teams produced working prototypes. Many were highly functional and potentially effective devices. However, in a final competition and showcase, Ms. Sandi Mugford left the class with one device. See Fig. 3. Her thank you note to the class is included below.

January 15, 2014

Dear Dr. Fleisig and 1st year Engineering Students,

I have been very remiss in not sending you all a note of sincere thanks for your industry and imaginative devices created on my behalf.

It occurs to me that you may actually not be aware of how profound a change you've made in my daily life. I no longer have to plan, strategise or organize my activities around optimum times to fuel the car.

Now, I'm able to pump gas with wild abandon whenever the need arises or for the pure joy of using my "mac fuel lever" as I've dubbed it!

The opportunity to learn with each of you has been an amazing journey and enriched my life in so many positive ways. Again, my most generous gratitude to each of you for the collaborative efforts on this project.

With much affection, Sandi Mugford

The resulting device garnered attention from the local media [5][6].

VII. Discussion

During and following the course, interviews with participating students were held to examine their perspectives on the experience.

Feedback from students, teaching assistants, and community has been excellent. A small sample of quotes from students who participated in the IMPACT Project in the fall of 2013 are shared below.

"This project was also helpful because it was an opportunity to observe and learn about the different stages involved in project design and problem solving. I also learned how to provide constructive feedback that will be of benefit when working in group projects. This project was also a excellent exercise in 'thinking outside of the box' and using our creative problem-solving skills."

"It was a great experience and I mostly enjoyed interacting and collaborating with students outside of my faculty. In addition I really enjoyed being able to utilize my biological knowledge and apply it to a real world scenario. The project was extremely organized and the staff and students were very friendly and respectful. I would strongly agree to the idea of a student team interdisciplinary project because it is a great way to integrate different faculties together and work towards a common purpose."

"I find the interdisciplinary project to be extremely engaging. It teaches students valuable transferable skills, allowing them to apply their 'in-class knowledge' to solve real-life problems. The interchange of ideas between different areas of expertise further enhanced the students' learning experience by addressing a problem using a multifaceted approach"

The interdisciplinary interactions between first-year engineering students lead to some unanticipated student reactions and reflection.

The Rehabilitation Science students were enrolled in a two-year professional Master's program preparing them for registration as Occupational Therapists. The designers and reviewers were separated by at least four years of age and an undergraduate degree. Interviews revealed that students commonly perceived the reviewers as experts. This created a difficult learning situation for some designers when the reviewers criticized their prototype. The designers often accepted the word of the reviewers without question. For the teaching assistants, this was an important point at which direction could be given with respect to examining the nature of the design problem, the value of expert opinion, and the role of critical thinking.

After the reviews with the Occupational Therapy students, the designers revised their designs and prototypes. In the following week, a second round of reviews, with the Department of Biology, was organized. The Biology students were undergraduates and graduates at various levels with the majority pursuing careers in medicine and health research. We hypothesized that interaction with these students might not be effective. The expertise of the Biology students seemed to have no clear bearing on the design project. However, our interviews with the students suggested that many of them immediately saw value in receiving an outsider's opinion, even if they did not view them as engineering experts. In fact, students often reported that the Biology students had provided valuable input with fresh perspectives and ideas.

VIII. Future Directions

In discussion with MIIETL (McMaster Institute for Innovation and Excellence and Teaching and Learning), it became apparent that the IMPACT Project model for interdisciplinary, experiential, and self-directed community-engaged learning is compelling. The trends in education include a changing demand in education [7]. MOOCs may be the future in teaching fundamental mathematics, science, and engineering science. However, bringing students unique learning experiences that raise their level of intellectual engagement from the perspective of Bloom's taxonomy [8] on the scale of large course with minimum resources could be addressed by courses following the IMPACT Project model. The future of courses, such as this one, would combine blended learning (i.e., moving lecture-type components online) and provide for further interaction amongst interdisciplinary arrangements of students in large classrooms specifically designed for this kind of interaction. Something most lecture halls are not adept at facilitating.

Acknowledgments

The authors would like to acknowledge the contributions of Ms. Sandi Mugford, her resilience is an example for us all. The time she spent with the students will be one of the defining university experiences for many of our students.

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Experiential Learning Paradigm Revisited

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Abstract— It is an old wisdom that experience is the best teacher. Well recognized in the trades, long before formal education became the norm if not the necessity to lay theoretical foundations in professional vocations such as engineering and medicine, it has been somewhat overshadowed by the development of virtual reality. It is now possible to tweak an experimental parameter in Boston or Oxford to change an experimental process set up in Moscow, as recently reported [1]. This too is a refinement of earlier successes reported in South Korea in 70ies.

The highly promising online learning, while meeting the basic educational needs of introducing theoretical fundamentals, falls short of ideal in engineering as it does not provide the hands-on component essential to complete one's formal education. A highly successful variant has been the development of "sandwich" courses whereby students spend half a year at a university and the other half in industry as internees. A less ambitious approach has been for students to be confronted with a task that needs specialist knowledge they then have to seek in order to provide the solution to the problem facing them. The fundamental shortcoming of this approach is in the students' ability to extrapolate the wisdom so gained to other problems that may be facing them later. In addition, the specific knowledge so gained is only a part of the mosaic needed fully to comprehend and tackle future challenges. Many such segments of wisdom are needed to acquire an overall pool of generic information expected of a trained engineer. Thus, within the limited time available for formal education, careful attention to the problem selection and their number needs to be addressed.

In the Australian context, the Australian Council of Engineering Deans has published a report [2] that proposes "...that engineering practice (including research) should be placed at the centre of curriculum design and delivery, and that students should be encouraged, from the start of their studies, to develop their identities and self-sufficiency as 'student engineers'."

This paper aims at examining the experiential learning paradigm as a pedagogical tool especially in the current setting of budget constraints, knowledge explosion and increasing student numbers.

Keywords— experiential, learning, engineering, pedagogy, research

I. Introduction

Learning as a pedagogical endeavor has many modalities. The traditional modality in institutions of higher learning has been by formal lectures or as in ancient Greece, by a dialogue between the teacher and the student, with perhaps a bed of sand between them for drawing diagrams to illustrate an obscure point. As professions developed, specialist skills were necessary, and more complex presentations evolved into the lectures of today. The utility of these has been questioned as to their effectiveness in the learning process, resulting in highly analytical approaches.

It has been realized a very long time ago that "learning by doing" is the most effective, as enshrined in the wisdom of Confucius (579 – 451 BC) who reputedly said "*I hear and I forget, I see and I remember, I do and I understand*". This old learning modality has been recently formally expressed by a number of new practitioners, most notably Kolb [3].

The experiential learning cycle is typically formalized by Kolb as consisting of first, a concrete experience in which involvement of participant(s) is the key. The information gathered in the process is then reviewed and questions asked about its relevance and utility as a stepping-stone to further progress. The next step involves making sense of the data by interpreting them and understanding relationships between them. The final step in the cycle is when the learner(s) consider how to put into practice that which has been learnt. The success of such an approach depends on the enthusiasm of participants and their willingness to learn, while under guidance of a mentor.

While widely applicable, the experiential approach has particular application in engineering design and research. Both activities require hands-on engagement, exploring the unknown, and in the case of engineering design, synthesizing information gathered to date to satisfy a given need. In the research mode the participant is probing the unknown, creating new knowledge and extending the outreach of his profession.

The aim of this note is to examine the experiential learning paradigm as a pedagogical tool, especially in the current setting of budget constraints, knowledge explosion and increasing student numbers and its role in research.

II. Background

The traditional method of imparting knowledge through formal lectures has been questioned as to its learning effectiveness. In addition, development of online learning using e-technology is becoming popular because of its obvious advantages, among others: instant recall of wanted material, low running costs, decreased demand on the conventional infrastructure, preparing the future professional for life-long self-learning and professional development.

While it is undeniable the many advantages online learning offers, it has one major drawback in that it inherently does not provide hands on experience essential in professions such as engineering and medicine. It is against this background that its utility has to be gauged overall.

III. Experiencial Learning within the Blended Learning Sphere at UWS

The University of Western Sydney (UWS) is committed to a University wide strategy for developing engagement, flexibility and community links in tertiary education known as Blended Learning (BL). At UWS BL *'combines times and modes of learning, integrating the best aspects of face-to-face, community based and online interactions for each discipline'*. To implement this strategy UWS has employed blended learning specialists to work alongside academics in development of learning activities. In the School of Computing, Engineering and Mathematics, initial progress has primarily focused on the use of information and communication technologies (ICT). This initial work lays the foundation needed to support development of experiential learning over the course of a program.

Experiential learning can be summarized as 'methods of teaching that involves learning from experience, from a direct encounter with the phenomena being studied' [4]. In this model learning begins with concrete experience (doing, having an experience), which leads to reflective observation (reviewing, reflecting on the experience), and abstract conceptualization (drawing conclusions, learning from the experience) in order to move on to active experimentation (planning, and then ultimately trying out what one has learnt). Of consideration when setting experiential activities is the time needed for students to complete the task. BL strategies enable flexible arrangement for delivering content. With capabilities of recorded lectures, discussion boards, group collaboration tools and webinars, units can be structured to allow students to go into placements or cadetships while completing their degree. Attendance on campus at a certain time of day becomes optional. This then gives a balance of real world experiences and theoretical concepts, which can be readily applied in the future situations encountered in the field.

Some examples of ICT tools that support experiential learning are included below:

- Recorded lectures give students the flexibility of time to engage in hands on experiments.
- E-portfolios aid students in documenting all of the stages in the experiential learning model, allowing for self-assessment and easier marking of assessments.
- Online simulations of real world situations may prepare students for otherwise un-safe situations.
- Where the number of students affects the ability for site visits the number may be reduced by having a representative from each group participate in the site visit and communication to the rest of the group via synchronous webinars, allowing group members to ask questions.
- Field experts can be invited as guest online speakers from anywhere in the world, with minimal disruption to their schedule.
- Students can participate on a project remotely through online collaboration tools (GoogleDocs, Blackboard Collaborate, Wikis and Google Forms).
- World project databases such as HCD Connect provide worldwide reach of real clients and real projects.

Using experiential learning as assessable activities provides wider and greater real world recognition (compared to mark accumulation) of efforts when done in collaboration with people from the industry or in competitions from other participants nationally or worldwide.

IV. Teaching Engineering at UWS

Within the Engineering programs at UWS, experiential learning is introduced in first year, typically in laboratory experiments, and progressively increased throughout subsequent years, culminating in a Major Project in the final year of study. During the course of study, laboratory sessions are replaced with individual and group projects. Examinations and tests are given less weighting in advanced years. The gradual increase of emphasis on experiential learning throughout the program enables students to transition from the heavy examination structure of high school to the problem solving and applied practice of an engineer.

An example of experiential learning at UWS is demonstrated by the widely popular Solar Car project. From laboratories to championship tracks, with the single goal of joining the World Solar Challenge, this UWS student driven venture has taken experiential learning to unexpected heights. The project, which started as a high school model car challenge, has turned into a final year engineering project and has paved the way for UWS' international recognition in the World Solar Challenge [5]. With the help of academic advisors, promoters and sponsors, the students and entire Solar Car Club have had first-hand experience in taking theory to practice. The project required integration of whole sets of intricate, interdisciplinary experiences to take this project on the road. The project is ongoing and continuously recruiting new members, even including a few High School students. Experiential learning, such as the Solar car project, provide engagement, motivation and hands-on learning from as early as first year and through to final year.

Current and future work within the UWS Engineering faculty includes;

- curriculum mapping, which develops the program structure to introduce, develop and ensure positive graduate outcomes.. Knowledge acquired through responsible engagement and appreciation of multifaceted diversity in an evolving world is achieved by using real-world projects, such that students understand and value ethical conduct, intellectual integrity and professionalism.

- inclusion of the national engineering learned society, (Engineers Australia) generic engineering graduate attributes into the development of Learning Outcomes, assessment tasks and in class / online activities within individual subjects.
- suggesting ways of using real world projects or clients for designing, evaluating and reflecting on product proposals.
- recording demonstration / lab introductory video presentations for students to watch before laboratory sessions to give them more time for doing the experiments and discussing their results.
- recording mini lectures that would provide students with easily searchable "just-in-time" information for particular problems they need to solve.
- encouraging self-reflection and keeping process diary through e-portfolios.
- combining assessable projects with other units.
- showcasing project outcomes to a wider audience.
- using real data for design proposals

Project based assessments are commonly structured into third and final year engineering projects

V. MODALITIES

Essential though it is in the training of engineers, experiential learning as a part of formal curriculum, is necessarily restricted in its duration, quality and extent, apart from any other limitations. The formal course is of minimum three years (the Bologna model) or four in Australia, and is also subject to very limited institutional funding and infrastructure. Focusing on Engineering, the accent is on utility in addition to its hands on element during the formal undergraduate course,

The optimal solution would be to simulate the work-place environment as much as possible such that a student may familiarize himself with not only the work ethic, Occupational Health and Safety (OHS) issues, but also acquire awareness of challenges of working within a realistic budget when creating a product (an open ended solution to design specifications) subject to strict scheduling and quality standards. Coming from such a versatile educational background where all these elements are included, such a young graduate would be immediately useful and productive member of any company that would be fortunate enough to employ him.

An ideal experiential model would be a "factory" operated by the university in which Engineering would have its place alongside other disciplines: Business, Humanities, Graphic Arts, etc. The factory would be run by professional engineers who would supervise students engaged on real projects obtained on contract from industry. Other aspects of an enterprise would be occupied by students in relevant disciplines mentioned before, in order for the factory to deliver a product holistically.

At Carnegie Mellon University [6], this has been practiced in their Engineering Product Design, which not only produced items won in bids from industry, but produced all the documentation necessary for their marketing. Associated developments required input from non-engineering departments from the university and were a part of experiential training for their students as well.

Another variant of the above is practiced by the Hong Kong Polytechnic University [7], which has a multistory building on its Kowloon campus housing all aspects of product manufacturing. Because their Engineering Department also offers Industrial Product Design, they produced items that have had international marketing potential, such as a small hybrid engine two-passenger vehicle. The experiential experience included not only product design, but also its manufacture, which apart from its unique sand casting foundry, offered hand operated machine tools, robotics, automated manufacturing and SCADA system. A graduating student would be able to acclimatize very quickly to the real-world environment with such an experiential background.

University of Technology Sydney offers "sandwich" courses whereby students spend half a year attending university classes and the other half of the year working with participating industry partners. All of their graduates have virtually guaranteed employment upon completion of their course, which admittedly takes longer to complete than the conventional full-time variant.

Possibly the "easiest" experiential component course to facilitate is through association with the local industry on the part of the academic responsible for the course. This is predicated by close liaison with industry through faculty personal contacts such as may be enabled by memberships of local professional associations (such as ASME, MEA, EA, etc.) and membership of company boards, attendance at industry fairs and similar.

The latter approach was adopted by one of the authors (VI) when teaching Mechatronic Engineering Design [8]. It was a success in every way: students worked on real projects at company premises and under supervision of practicing engineers. Some of the students that excelled were spoken for by the company they had worked for such that it employed them immediately after graduation. The downside of this approach is that it places a considerable demand on the academic's time to organize such activities, in addition to the usual teaching load and research activities. It would be extremely helpful and beneficial to have a faculty office dedicated to welfare of students to take over the responsibility for maintaining a pool of placements for students through its intensive and dedicated marketing. The local industry should know that there exists an opportunity for student help "for free". Additionally, they get the academic responsible to provide a professional advisory back up – a "free consultancy" if ever needed.

In a specifically Australian context, given a good will to overcome extensive bureaucratic obstacles, it is possible to engage Institutes of Technical and Further Education (TAFE) to provide practical experience for university students of Engineering, as TAFE institutes are especially equipped for their role of training future tradesmen and technologists – both highly desirable interim experiential phases of a trained Engineer. Such a development needs an influential champion to bring the two educational institutions together for the mutual benefit, as well as that of their students.

The above gives a few examples of how experiential learning may be utilized for the benefit of everyone involved, particularly students, who are at the hub of the whole exercise.

Another aspect of experiential engagement is through higher degree research, where a student is left almost entirely to his / her devices, but under the mentorship and supervision of an Advisor. At the graduate level, this activity provides a student not only with an opportunity for some original contribution to the body of knowledge, but it also labels the student as an expert in a narrow field – thanks to this solitary and unique experiential activity.

Engineering education without a mandatory experiential component is not unlike Applied Mathematics and therefore of limited practical utility. Even overemphasis on online learning is subject to the danger of providing insufficient experiential component expected of an adequately trained graduating engineer.

VI. Conclusions and Recommendations

Experiential component of learning is an essential aspect of an academically trained Engineer. Engineering curriculum without the experiential component would be tantamount to a course in Applied Mathematics – interesting and intellectually challenging, but of little value in Engineering Practice.

There are many opportunities to form strong liaisons with industry, through internships, collaboration in student projects, especially through its External Advisory Boards. These should all be utilized for industry is the ultimate employer of most graduates.

Use of information and communication technologies can aid the implementation of experiential learning by creating flexibility of how and when content knowledge is learned, creating accommodating study schedules for internships and project-based activities.

It is also highly recommended that a close collaboration of university Departments of Engineering with Institutes of TAFE in Australia - or their equivalents elsewhere – be established as a matter of course, for the benefit of all the participants.

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