Volume 29 Number 1 2013 ISSN 0949-149X

The International Journal of Engineering Education

Contents

Contributions in: PBL, Innovation, Team work, Creativity, Entrepreneurship, Service Learning, Leadership, Engineering Thinking, Motivation, Academic Performance, Laboratory Development, STEM, Outreach, Professional Skills, International Engineers, Technological Tools, Mechanical Engineering, Computer Engineering, Process Automation, Control Systems, Manufacturing

Understanding innovation competency is the first step in fostering innovative engineers as conceptualizations can both enhance and inhibit innovative behaviors. Though literature is replete with discussions on conceptualizing innovation competency, there is much disagreement regarding its concepts as well as about how to put into operation the concept in teaching and learning. This paper addresses the disagreement through an empirical study in one problem- and project-based learning (PBL) curriculum. A case study on an engineering master program, Environment Management (EM), in Aalborg University, Denmark, has been conducted to answer the following questions. 1) How have academic staff conceptualized innovation competency in the PBL curriculum? 2) How have students conceptualized innovation competency in the PBL curriculum? 3) What are the similarities and differences between academic staff and students' conceptualizations? 4) How are academic staff and students' conceptualizations on innovation competency differentiated and related in concepts in the literature? This study encompasses eighteen in-depth interviews with academic staff and students. Conceptualizations on innovation competency were identified by analyzing the narratives of interviewees and coding the transcriptions into pre-prepared categories, based on the theoretical framework inspired by activity theory. The analysis of empirical data indicates a collaborative nature of innovation competency in the PBL curriculum; emphasizes the empowerment of individuals during teamwork; displays the interaction between individuals, teams and the social system. Furthermore, it describes innovation competency as a wide range of human abilities and processes, such as personal ability (in finding real-life problems and formulating research questions), interpersonal ability (by being open and responsive to diverse perspectives and intentionally constructing collaborative relationships), and implementing ability (by effectively implementing their ideas in useful projects).

Keywords: conceptualizations; innovation competency; problem- and project-based curriculum; activity theory

Project and problem-based learning (PBL) has been widely recognised as an active, collaborative, cumulative and integrative learning approach that engages learners, motivates team creativity and centres on practical education. On the other hand, traditional lecture–tutorial teaching is often criticised for being a passive, surface learning and exam-focused approach. In spite of these evidence-based observations and claims over the years, the traditional lecture–tutorial teaching approach still dominates as the preferred teaching approach at Australian universities. This study sets up a control environment to compare these two teaching and learning approaches by analysing data from students' actual performance, course evaluation and expectation in two large undergraduate engineering courses in 2009 and 2010. The evidence reported in this study is broadly interesting in that both courses were taught by the same teaching staff using two entirely different learning and teaching approaches to the same cohort of students in the same semester within the same degree program. The analysis shows that there are significant differences between the students' actual performance, course evaluation and their expectation. Such conflicting differences may be some of the reasons that may negatively impact teaching staff deterring them from switching to PBL from traditional lecture-tutorial teaching.

Keywords: PBL; traditional teaching; course performance; student evaluation

The 'Learning and Innovation Factory for Integrative Production Education (LF)' at the Vienna University of Technology (VUT) is the basis of the case study presented in this paper. One of the key objectives of the Learning Factory was to develop an immersive learning environment resulting in an integrated hands-on and 'heads-on' educational laboratory. One key-challenge was the utilization of the potential of problem-based and action-oriented learning and its transfer to higher education in industrial engineering. The teaching methodology harnesses the advantages of an interdisciplinary, experience-based and applied approach to learning and knowledge transfer, in order to build and hone the key competences of future industrial engineers. This is done in the context of a comprehensive approach to the Product Development Process, spanning the entire genesis of a product from product conception to serial production. Therefore, the pilot course was dubbed the 'integrative Product Emergence Process' (i-PEP). The presented case study shows the first results with respect to competence development for industrial engineers and presents the current approach of the VUT-LF and intended future developments.

Keywords: hands-on training; industrial engineering education; learning by doing; immersive learning environment; problem-based learning; action-oriented learning

In this paper, the authors present a framework for examining the role of computers in supporting creative collaborative engineering design. It is argued that the affordance of computational technology for supporting both representational and relational aspects of design is essential for creative collaboration. Representational aspects refer to the creation of verbal descriptions or visual sketches necessary for the generation and sharing of ideas. Relational aspects refer to support for communicative and collaborative aspects that are the cornerstones of teamwork. To illustrate the usefulness of the proposed framework, the authors present empirical findings from a case study of a collaborative engineering design project. In this study, a team of engineering design students successfully appropriate available technologies to create collaborative practices. The design practices of this team are compared with another team working on the same project but that met face-to-face. Through this comparison it is shown that computation technology can be used creatively by design teams.

Keywords: engineering design; design and technology; student design teams; collaboration; teamwork; creativity; representations; affordances

The number of entrepreneurship programs at universities targeting engineering students has grown substantially in the last decade. However, few research studies have examined the practices and beliefs of instructors in these programs. Understanding these beliefs will help the development of pedagogical and theoretical models to drive entrepreneurship education. The purpose of this paper is to gather information on instructors' beliefs and teaching practices relating to engineering entrepreneurship education. Three research questions were addressed in the study: 1) How do faculty members define the entrepreneurial mindset? 2) Do faculty members believe that the entrepreneurial mindset is something that can be developed? 3) How do faculty members teach entrepreneurship; is there a relationship between their teaching practices and their beliefs? The study was conducted in two phases. In the first phase, twenty-six instructors of entrepreneurship participated in an in-depth structured interview focusing on their perceptions of entrepreneurship education. The results of this study led to the construction of an online survey that was administered to 37 instructors at three institutions in the second phase of the study. Results showed that faculty tended to believe that the entrepreneurial mindset is a function of both innate characteristics and skills that can be built through instruction. Faculty also felt that entrepreneurship programs should focus on venture and be taught through formal programs. The participants advocated for the use of experiential learning for teaching entrepreneurship.

Keywords: entrepreneurship education; instructor beliefs; innovation

The main purpose of this study was to develop a feasible instructional model for blended TRIZ (Theory of Inventive Problem Solving) creative learning and a verification mechanism. This study summarized the teaching design contents of blended creative learning based on a literature review, and integrated them with TRIZ to develop the teaching model for blended TRIZ creative learning. This model comprises three parts: traditional teaching, online teaching, and learning evaluation. The results of experimental teaching and questionnaire surveys showed that, students are positive and affirmative about the four aspects of the teaching model, namely learning effectiveness, learning attitude, application of the learning platform, and TRIZ creative learning. Moreover, in order to improve the teaching model, this study proposed a verification mechanism, and summarized the items to be improved. Furthermore, this study proposed specific suggestions and revised the model based on the connection between the teaching model and teaching design focuses, in order to achieve the goal of teaching design, improving teachers' creative teaching quality, cultivating a positive attitude towards innovation in the students, and further enhancing their creative ability.

Keywords: blended learning; TRIZ; creative learning; Design and Verification of Teaching Model

How best can one educate the engineer of 2020 and beyond? How can institutions meet increasing demands to produce graduates with sound scientific fundamentals and essential non-technical skills, while ensuring they are knowledgeable of state of the art advances in technology? To better frame the discussion, I present an analysis of historical technical innovation and engineering knowledge trends, and provide a perspective on the practice of parsing technological knowledge to define new engineering disciplines. Evidence suggests that the emergence of new engineering disciplines has historically matched the pace of increases in technological innovations, with both the number of disciplines and technological innovation doubling at a rate of between 31 and 35 years. Continued success of the parsing strategy requires increased emphasis on certain engineering education trends such as instilling communication and teaming skills, an emphasis on life-long learning skills, and mechanisms for interdisciplinary integration. Lastly, I recommend that a proactive and thoughtful mapping of future disciplinary demarcations could prove more beneficial than the current ad hoc process.

Keywords: engineering education; innovation; curriculum; communication

Successful engineering students should possess competence in both technical and professional traits such as creativity and leadership. This paper investigates how an engineering service learning module with a focus on leadership can affect engineering students' confidence level for technical and professional traits. This leadership module was offered as part of our first-year course that aims to expose freshmen to general engineering principles. The research question in this paper addresses what is the effect, if any, of an engineering service learning module on (1) the confidence levels of women and men as it relates to eleven National Academy of Engineering (NAE) and ABET engineering traits and (2) their confidence in and perceptions of leadership. Data were collected via two surveys administered at the beginning and end of the module. One hundred and thirteen students returned both NAE-ABET surveys and fifty-two returned both leadership surveys. A two-tailed Student's t-test with equal variance was utilized with a confidence level of both 95% and 90% to test for statistical significance. The results showed leadership module students increased in confidence in all NAE-ABET and leadership skills, while students not in the module increased less or decreased in confidence in most NAE-ABET skills. Women in our leadership module increased their confidence on all NAE-ABET skills, while other women experienced no significant increase in confidence level. Within the leadership module, women's confidence increased more than men's confidence in all but four NAE-ABET traits. The statistical trends of students' survey responses and qualitative analysis of the comments show no negative impact on their confidence in technical and professional skills when compared with students in the more technical modules. Moreover, qualitative responses from women indicate overwhelming appreciation for the experience and skills gained from the leadership module, as well as increased confidence for women as engineers.

Keywords: service learning; design; outreach; first-year; leadership; teamwork; professional skills

Engineering education has been striving to find good ways to improve students' learning of engineering. However, non-technical professional skills such as communication and interpersonal skills, teamwork, and creative and intuitive thinking skills are also seen as essential for engineers, and especially for leaders. The portfolio practice has proved to be effective in supporting students' learning, as it allows them to document evidence of their learning and to reflect on personal growth. This paper reports a case study on implementation of the portfolio practice in an engineering leadership block curriculum and assessment of students' perceptions of this practice. It also provides implications for advancing engineering education with this approach.

Keywords: block curriculum; engineering education; engineering leadership development; portfolio assessment; student learning and reflection

It is well established that students' misunderstandings and misconceptions frequently impede learning processes and frustrate their best efforts. Little is known about how they relate to engineering thinking. We claim that some learning difficulties are common to several engineering disciplines. The aim of the study presented in this paper is to answer the question: What engineering-thinking misunderstandings and misconceptions are typical of students in the areas of electronics, mechanical and software engineering? Based on analysis of interviews with experienced lecturers, this paper presents three levels of students' engineering-thinking misunderstandings, according to their generality. The first level relates to misunderstandings of specific content learned in a concrete engineering discipline; the second level deals with more general students' problems in interpreting and integrating knowledge, which they typically make in several engineering disciplines; and the third level describes misunderstandings characteristic of students in most engineering disciplines. In addition, we discuss the match between the misunderstandings of students studying engineering disciplines and the system of categories, which characterizes engineering thinking.

Keywords: engineering design; engineering thinking; misunderstandings, misconceptions

Tutors have been shown to have positive effects on a multitude of important student outcomes in educational settings, and are a cost effective, valuable, but often under-utilized resource. Although extensive literature exists on motivation, findings have not been rigorously applied to understanding tutors' motivations for participating in unpaid tutoring programs. The purpose of this study is to investigate motivational factors behind students' participation in an in-class peer tutoring (ICPT) program utilizing a combined inductive approach and the established functional approach theoretical framework. Tutors were interviewed using a semi-structured format with an open-ended interview protocol using both general questions about their experience with ICPT, and specific questions related to the functional approach. Interviews were analyzed by two researchers using a multi-phase collaborative analysis procedure. Our analysis indicates that the most prevalent reasons students are motivated to participate in ICPT programs are to reinforce engineering concepts, to help others, and to contribute to courses and the department. Students were also influenced by career and social factors. Findings suggest that token compensation did not have a major affect on motivation. Future efforts investigating volunteer tutoring programs should use a modified functional approach that includes factors found in this study. These findings can help improve the recruitment and retention of volunteer tutors for this and other programs. This study also illustrates that it is possible to maintain an effective peer tutoring program at no cost through the use of volunteers.

Keywords: tutoring; motivation; functional approach

Internationally, the recruitment, management and retention of students has become a high priority for universities. The use of information technology systems and student data by institutions to understand and improve student academic performance is often referred to as 'academic analytics'. This paper presents an academic analytics investigation into the modelling of academic performance of engineering students enrolled in a second-year class. The modelling method used was binary logistic regression, and the target predicted variable was 'success status'—defined as those students from the total originally enrolled group that achieved a final unit grade of pass or better. This paper shows that student data stored in institutional systems can be used to predict student academic performance with reasonable accuracy, and it provides one methodology for achieving this. Importantly, significant predictor variables are identified that offer the ability to develop targeted interventions to improve student success and retention outcomes.

Keywords: academic analytics; student academic performance; engineering education; binary logistic regression

This paper reports on the evaluation findings and the lessons learned from performing take-home laboratories in four undergraduate mechanical engineering courses at the University of Rhode Island. In this project, students were provided with a compact, low-cost kit with which they can perform an experiment at home using their own PC/laptop. A Student Survey was developed and used to collect perceptions of curricular effectiveness from the URI (University of Rhode Island) students on a post-course basis. In addition, pre- and post- quizzes were administered in the affected courses. The evaluation showed several things. First, student responses on the surveys and results of quiz grades indicated that the kits played an important role in the conceptual understanding of the course material and application of the course content to real world applications. Second, across the four mechanical engineering courses in which the kits were implemented, the majority of students consistently reported that they were comfortable working on, and with, the take-home kits independent of a lab or instructor. They also reported that both the software and the hardware of the take-home kits were easy to set up and use. Third, one semester after the kits were first placed into service, there has been a steady increase in undergraduate Mechanical Engineering student interest in system dynamics courses as evidenced by an increase in the student enrollment in three of the affected courses.

Keywords: evaluation; laboratory at home; mechanical engineering laboratory education; take-home kit

Many educational teaching methodologies are designed from a specific pedagogical stance that relies on known teaching models like the T4E that promote active learning, learning intentions, lesson arrangement, and effective delivery of teaching style. In this paper we describe our study on "CAPstone, Unique Learning Experience (CAPSULE)" methodology that promotes engineering-based teaching and learning model at the high school level. The purpose of this study is to train teachers in using the new methodology and then observe their experience with the implementation in their classrooms. This study will contribute to our improved understanding of how high school students absorb STEM subject content. Data for the study were collected during the teachers' summer professional development workshops conducted in 2010 and 2011 using CAPSULE methodology. A total of 51 high school teachers participated in the study. During these workshops each teacher develops a unique strategy for his or her classroom aimed at creating a sustainable learning environment for students to learn and retain STEM principals. The engineering-

based teaching and learning model emphasizes the engineering-design process and capstone experiences to relate the content of science to real-world applications. Our findings indicate that teachers' uninformed perception of engineering-based teaching influences their pedagogical practices. Our findings also indicate that CAPSULE methodology can positively affect STEM teachers' in-class pedagogical behavior and their classroom teaching. Lastly, our research has implied that the CAPSULE methodology can have an impact on students' ability to connect STEM concepts to real-world application resulting in better understanding of STEM in their environment.

Keywords: capstone experience; engineering-based teaching and learning; engineering-design process; research; design

K-12 engineering education has recently received increasing national and international attention for stimulating interest and improving learning in mathematics and science. This paper describes a case study of K-12 engineering education in which a real-world engineering example is integrated into a computer simulation learning module to improve student understanding of three important concept pairs in high school physics, specifically, in Newtonian mechanics. The three concept pairs include: linear displacement vs. angular displacement, linear velocity vs. angular velocity, linear acceleration vs. angular acceleration. The module has interactive graphical user interfaces requiring student inputs to promote active learning. A total of fifteen high school students participated in the present study. A pre-test, a post-test, and a questionnaire survey were administrated to assess student perceptions about the three concept pairs as well as student learning gains. The coefficients of reliability (Cronbach's alpha) of the assessment instruments were 0.937 and 0.969, respectively. Students reported positive experiences with the developed computer simulation module, and stated that, via the use of the simulation learning module, they developed a better understanding of the conceptual difference and the mathematical relationship between two concepts in each concept pair. Students achieved an average learning gain of 46.7%–71.4%. Finally, the present study reveals that the three lowest learning gains are all related to angular quantities: angular displacement, angular velocity, and angular acceleration. This implies that more educational efforts should be made to improve student understanding of these angular quantities.

Keywords: K-12 engineering education; real-world engineering examples; computer simulations; student perceptions; physics; student learning gains

The formal introduction of professional skills to the graduation profile of engineering students has highlighted the importance of non-technical skills in engineering programs. However, there is little agreement among academics as to both the extent of knowledge required in particular skills and what is the right mix of the technical and professional skills. These two issues are reviewed in this paper in terms of graduate attributes from the perspective of employers of mechanical engineering graduates. A survey of Chilean industry revealed a significant discrepancy between the desired and actual graduate profiles with almost all attributes rated as relevant but not used frequently or vice versa. Interestingly, the least discrepancy and the least relevance were found for technical skills with particular reference to the design and conduction of experiments. The apparent importance of professional skills over technical skills is discussed in the context of employers' expectations that are not necessarily aligned with current educational programs. It was concluded that instruction in professional skills should be embedded into the technical courses to promote active, reflective and student-centered learning.

Keywords: ABET outcomes; accreditation; case study; engineering education; graduate attributes

This paper presents findings from an exploratory study designed to examine the role of a cooperative education term in the integration of international engineering graduates (immigrant engineers) into the Canadian engineering profession. The participants in this study were all enrolled in a university-based qualifications recognition program, of which a co-operative education term is one critical component. Data were gathered through focus group interviews, which were designed to obtain their perceptions of the cooperative education experience and its relationship to their career development. Data were interpreted through a theoretical framework of cultural categories and social and cultural capital, with the aim of discerning enabling and disabling aspects of a cooperative education experience to immigrant professionals' career development. Data reveal that the most profound obstacles concerned participants' expectations and competencies in the cultural norms and interactional styles that are unique to the North American professional workplace. The implementation of a professional practice component in the academic portion of the university-based program (prior to cooperative education placement) helped students to develop a heightened awareness of cultural differences in the workplace. The co-op term built on this preparation and equipped them with opportunities to recognize and develop social and cultural capital in the Canadian context, relative to the cultivation of professional skills (soft skills) and exposure to mentoring and networking opportunities. Implications are drawn regarding the integration of immigrant professionals and the relationship of findings to other under-represented groups.

Keywords: cooperative education; immigrant engineers; social and cultural capital; professional integration

The development of the Internet has led to a great transformation in different spheres of society, including education. The question discussed in this research is not whether this transformation is positive or negative. This study aims to discuss the potentialities of Web 2.0 tools in education, observing how it can be used in Engineering Education models. The question that we want to help answer is: How can engineering professors use Web 2.0 tools, for example in a blog, in teaching strategies to create a motivational learning space? A methodology based on collaborative learning was proposed to students in the Industrial Engineering Fundamentals discipline using Web 2.0 tools to evaluate its potential to aid autonomous learning. It was concluded that Web 2.0 tools have a large potential in Engineering Education. This methodology created a space in which students have a more active role in the learning process.

Keywords: collaborative learning; industrial engineering; Web 2.0

This paper is a detailed technical description of the Progressive Learning Platform (PLP). The PLP system is a System on a Chip design with accompanying tools reflecting a contemporary CPU architecture. The paper is intended to be a reference for users who are interested in using the platform, developers who intend to contribute to the project, educators who would like to adopt PLP in their computer engineering course, and engineering education researchers who would like to use PLP as a vehicle for conducting research. All hardware components of PLP are written in Verilog HDL, are open source, and are freely available. To support the hardware components, a unified assembler, cycle accurate emulator, and board interface software package is included. The software is written in Java, works on Linux, Windows, and Mac OS, is open source, and is freely available. The PLP hardware and

software components are licensed under the General Public License version 3 to encourage open access and contribution. All parts of the system are publicly hosted and a public mailing list is used to serve as a communication channel between users and developers of the system.

Keywords: instruction set design; computer systems organization; collaborative learning; computer science education; modeling of computer architecture; learning technologies; educational simulations; user generated learning content

This paper deals with the implementation of virtual reality technology as a higher level of e-learning education comes into the teaching process. It presents the design and development of a Web-based virtual laboratory architecture that supports laboratory training in the study of technological process automation. The proposed architecture provides several advantages to institutions offering e-learning and distance education courses in Industrial Automation. It facilitates the process of learning over the Internet by providing a Web-based user interface that allows remote users to access and control several physical models of technological processes and also verify to control programs, which are also developed on the basis of intelligent control methods, via a virtual model without damaging the system equipment. The architecture presented in the paper is not dependent on a specific SLC hardware or software configuration and offers the possibility of increasing the efficiency of the pedagogical process and developing the students' creativity, practical skills and proficiency, with an accent on the possibility of developing optional solutions in the field of automatic control of technological systems.

Keywords: virtual laboratory; remote access; industrial automation; virtual model; physical model of technological process

This paper describes the development of a low-cost home-made microcontroller based temperature control system. The system has been developed to support the practical sessions in undergraduate teaching of the automatic control theory course at the Near East University. The thermal plant was made from a plastic box consisting of a low-voltage heater and a semiconductor temperature sensor. The temperature inside the box was controlled using a microcontroller development kit employing a PIC18F4520 microcontroller, and providing a PWM (Pulse-Width-Modulator) output for the heater. Various digital controller algorithms and PID tuning methods can be programmed and tested using the kit. The developed kit enables students to control a laboratory scale thermal plant by learning to program the microcontroller in C. In addition, students can learn the principles and application of the important relay-based PID auto-tuning algorithm to control the plant.

Keywords: teaching control; microcontroller based control; PID auto-tuning; temperature control

Promoting excellence in manufacturing emerges as a strategic goal for the years to come, both for industry and society; manufacturing education has been identified as a major driver to achieving this goal. However, the pace of economic, social and technological change has increased the gap between the competences needed by industry and those provided by the universities' curricula. This requires an increasingly integrated approach by academia and industry in order to afford the problem of engineering competences' obsolescence. Framed in the above premises, the aim of this paper is to present the results of a two year postgraduate training program aimed at developing a new archetype of human capital to face the requirements of Intelligent and Sustainable Manufacturing. The case study presented in the paper addresses the needs for providing manufacturing education to meet the challenges in terms of "who"—the profile for the next generation of manufacturing engineer; "what"—the new system for education and its contents, and "how"—innovative learning approaches and strategy to incentive the development of competence. The findings demonstrate the radical innovation in developing the next generation of engineers for Intelligent and Sustainable Manufacturing and the importance of a learning environment that is strictly based on virtuous industry–university partnerships.

Keywords: intelligent manufacturing; competences; manufacturing education; industry–university partnership; entrepreneurial engineer

Not all students are able to use didactic manufacturing cells in order to experience real-life project development, owing to their cost and availability. Given the advances in communication media, such as the Internet2 network, which is designed for education purposes, it is easier for universities that have such manufacturing cells to share their resources. Under this premise, this paper presents the development and results of a case study involving a didactic teleoperated cell and the interaction between the ITESM in Mexico and the ESPE (Escuela Politécnica del Ejercito) in Ecuador, through the Internet2 network. The universities have similar graduate programs for automated systems but only the ITESM (Instituto Tecnológico y de Estudios Superiores de Monterrey) has a full didactic manufacturing cell: a CNC, a transportation band and an automated storage system. For the aforementioned cell, the software that integrates all the control systems was developed by students of both universities and operated as a server for client software given to the students of the ESPE. Practices and surveys for the students were developed and applied in order to compare the knowledge acquired between the students using the cell directly and the students using the cell via the teleoperated cell. This kind of system helps universities to provide more advanced courses and the subject treated in this paper seeks to support the feasibility of telepresence systems as a mean of education.

Keywords: education; teleoperation; Internet2; Labview; manufacturing cell