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
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 computational technology can be used creatively by design teams.

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

Sarah Zappe, Kirsten Hochstedt, Elizabeth Kisenwether and Angela Shartrand

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 that skills 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

Shi-Jer Lou, Chih-Chao Chung, Ru-Chu Shih, Huei-Yin Tsai and Kuo-Hung Tseng

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.

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

David M. Bowen

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

Ryan Shelby, Farzana Ansari, Eli Patten, Lisa Pruitt, Gretchen Walker and Jennifer Wang

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 highlights the potential for advancing engineering education with this approach.

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

Elena Trotskovsky, Shlomo Waks, Nissim Sabag and Orit Hazan

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

Shane Brown, David Street, Fred Barker and Larry Flick

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 qualitative and quantitative 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

Stuart Palmer

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

M. Jouaneh, J. Boulmetis and W. Palm, III

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

Ibrahim Zeid, Jessica Chin, Sagar Kamarthi and Claire Duggan

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-
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 critical components: the definition of force, the Newton's laws of motion, and the concept of momentum. These concepts are fundamental in physics and engineering, and understanding them is crucial for future scientists and engineers.

The simulation module, which is accessible online, uses interactive graphical interfaces to help students visualize the concepts. The module includes a virtual lab where students can conduct experiments and observe the effects of changing variables. The simulation is designed to be used in the classroom or for self-study and can be accessed through the website provided in the paper.

The study involved 200 students from grades 6 to 8, who were randomly divided into two groups: the experimental group used the simulation module, while the control group used traditional teaching methods. The results showed that students who used the simulation module had a significantly higher understanding of the concepts compared to the control group. The paper also includes recommendations for integrating similar simulation tools into educational curricula to improve student engagement and understanding in STEM subjects.
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

Daniela Perdukova and Pavol Fedor 230–238 Virtual Laboratory for the Study of Technological Process Automation

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

Dogan Ibrahim and Jamal F. Abu Hasna 239–247 Teaching PID Auto-Tuning Using a Low-Cost Control Kit

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

Giustina Secundo and Giuseppina Passante, 248–262 Developing the Next Generation of Engineers for Intelligent and Sustainable Manufacturing: A Case Study

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

Mauricio Hincapié, Oscar Salas, Miguel Ramírez, Baltazar Carranza Ite and Carina Viteri 263–273 Implementation of a Teleoperated Didactic Manufacturing Cell through Internet2 as a Means of Engineering Education

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

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