

# The International Journal of Engineering Education

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- Ahmad Ibrahim** 921–923 Editorial
- I. Ortiz-Marcos, T. Fransson, P. Hagström and C. Lhermithe** 924–932 T.I.M.E. European Summer School: An Innovative International Educational Experience

This paper presents an innovative experience that was developed by six European universities to teach a common course in an unconventional, remote way, to geographically-separate groups of students. The course is especially designed to enable engineering students to learn the basics of how the European social and sustainable model works, to acquire some basic cultural and religious awareness, and to stimulate transnational group discussions on such intercultural affairs. One over-arching goal of this T.I.M.E. (Top International Managers for Europe) European Summer School (TESS) course is to identify some of the challenges that an academic collaboration organization like T.I.M.E. faces for future education, especially considering that the computer literate and highly web-based children who are born today will, with their expectations of 'virtual 3D encounters', be entering university by 2030. This web-based, social interaction experience has been developed over the last four years. This paper gives the results.

**Keywords:** international experience; sustainability; innovative education

- T. C. Sheahan, E. J. Mason, D. M. Qualters, P. V. Poblete and X. Vargas** 933–944 Cross-National Evaluation of Learning Assessment in First-Year Engineering Students: U.S. Experience Applied at Two Universities in Chile

The need to demonstrate the quality of engineering student learning outcomes has intensified in recent years as the assessment movement has spread into engineering education, been widely adopted by accreditation agencies, and has been incorporated into international accreditation and curricular agreements. Developing quality standards and measuring learning levels can be difficult enough from campus to campus within a particular country. However, exporting and adapting such standards across countries and educational traditions and cultures is even more challenging. The present paper describes the portability of one system of assessment developed at a U.S. institution as applied to two engineering faculties in Chile. The process followed during the initial training and development provides some good insights into how assessment and quality improvement processes can be quickly implemented. However, the implementation required cultural shifts in how the program approached, and administrators and faculty thought about, assessment for quality improvement. The experience in Chile provides some lessons on the opportunities and potential pitfalls of carrying out such a process in other countries and programs.

**Keywords:** assessment; standards; engineering education; outcomes assessment; international standards; performance testing

- Glenn W. Ellis, Alan N. Rudnitsky, Mary A. Moriarty and Borjana Mikic** 945–957 Applying Knowledge Building in an Engineering Class: A Pilot Study

Although knowledge building pedagogy is being used increasingly around the world to support deep learning and to prepare graduates for the knowledge economy, its potential for improving engineering education remains largely unexplored. In this paper we review knowledge building theory, present a pilot study applying knowledge building in an engineering class and discuss questions raised by the study. In the pilot study, knowledge building was applied in one engineering class with 20 students. A narrative approach was used to initiate student knowledge building efforts and Knowledge Forum software was used to both support and keep a record of the ongoing discourse. The discourse was then analyzed to see if it reflected the determinants of knowledge building. A student survey and student reflections were used to record student perceptions. Discourse analysis showed that knowledge building clearly took place as evidenced by higher-level formulations of the problems, increased engagement, and more complex levels of discourse. Most students participated fully in the discourse resulting in a shift to orientation on idea improvement. While the study's findings support the promise and potential for knowledge building in engineering, it also raised questions that need to be addressed to broadly apply knowledge building in engineering education. These include: What types of questions or problems of understanding are most effective for engaging a broad range of students and generating substantive discourse? How should instructors best facilitate the discourse? And how can a student's ability to use knowledge innovatively be most effectively assessed?

**Keywords:** community; discourse; knowledge building; narrative

- Aditya Johri and Vinod K Lohani** 958–967 Framework for Improving Engineering Representational Literacy by Using Pen-based Computing

Representations such as free-body and circuit diagrams are central to engineering practice and proficiency. Developing and using representations is an essential skill that engineering students need to learn. In this paper we present a case study of the use of pen-based computing to improve representational literacy through dynamic knowledge construction and management activities among engineering students. We use case study data to develop a framework that explains how students can learn to construct and manage knowledge in a participatory learning environment that allows the creation, sharing, recording, and reflection of digital representations. Specifically, we propose that pen-based computing can enable efficient use of representational practices by providing a mechanism to externalize representations through visualization; by supporting awareness and feedback within lectures, and by allowing the co-construction of shared representations among faculty and students. Our framework emphasizes the contextually embedded role of technology in a learning environment and has implications for implementing technology in conjunction with curriculum development to provide meaningful learning experiences.

**Keywords:** representational literacy; participatory learning; pen-based computing

**Ruth A. Streveler, Ronald L. Miller,** 968–984 Rigorous Methodology for Concept Inventory Development: Using the  
**Aidsa I. Santiago-Román, Mary A. Nelson,** 'Assessment Triangle' to Develop and Test the Thermal and Transport  
**Monica R. Geist and Barbara M. Olds** Science Concept Inventory (TTCI)

This paper describes a methodology for creating concept inventories that can be used to validly and reliably measure student misconceptions in engineering and science domains. Following the successful impact of the Force Concept Inventory on undergraduate physics education, creating concept inventories in engineering subjects provides engineering faculty and researchers with tools for measuring the effect of new curricular and pedagogical tools that are designed to repair misconceptions. The methodology involved aligning the three corners of the assessment triangle: cognition, observation, and interpretation. In the cognition corner, engineering students' important misconceptions in thermal science were identified using a Delphi study and validated with current learning theory. In the observation corner, items for the TTCI were created and piloted. In the interpretation corner, classical test theory and item response theory were used to evaluate the performance of TTCI items and establish instrument reliability. Versions of the TTCI have been developed for heat transfer, thermodynamics, and fluid mechanics and piloted to over 1000 undergraduate engineering students. The heat transfer portion of the instrument consists of 12 items with an overall KR-20 reliability of 0.77. Item difficulty indices range from 0.25 to 0.75 and item discrimination index exceeds 0.20 for each item. These values are sufficient for using the TTCI as a tool to identify students' misconceptions in thermal and transport science in two ways: (1) as an informal classroom assessment or (2) to establish pre-test/post-test learning gains during a course of study.

**Keywords:** concept inventory; assessment triangle; misconceptions

**Rachel G. Campbell Murdy, Kela P. Weber** 985–991 Exploring Concept Maps as Study Tools in a First Year Engineering  
and **Raymond L. Legge** Biology Course: A Case Study

Concept maps are metacognitive study tools created and used by learners as reference maps describing relationships between concepts and specific domains. The purpose of this study was to investigate any correlation between the quality of concept maps and the mark distributions in a first-year engineering biology course. Major concepts of the course included prokaryotic and eukaryotic cell structure and composition, metabolic pathways, cell transport, genetic engineering and growth kinetics. Students were asked to develop concept maps and were allowed to consult their maps in a portion of the final exam. Maps were assigned a qualitative grouping of 1 (incomplete, preliminary map) or 2 (complete map) and were associated with final exam grades to compare the effectiveness of the concept maps. Students who provided complete concept maps had significantly higher 'open book' portion grades ( $p < 0.0001$ ) and overall final exam grades ( $p < 0.0001$ ) than students who handed in preliminary maps. The quality of the concept map was positively correlated to student performance in questions requiring conceptual skills as well as in the overall final exam grade.

**Keywords:** assessment; concept mapping; engineering biology; student performance

**Eleazar Gil-Herrera, Athanasios** 992–1002 Predicting Academic Performance Using a Rough Set Theory-Based  
**Tsalatsanis, Ali Yalcin and Autar Kaw** Knowledge Discovery Methodology

In an effort to predict student performance in an engineering course, Rough Set Theory (RST) is employed as the core of a knowledge discovery process. Student performance is captured in terms of successful course completion. Therefore, students are classified into two categories: those who pass a course and those who do not. The Rough Set Theory paradigm presented here analyzes each student based on a set of attributes. These attributes are collected through a series of surveys conducted in the first week of the course, allowing for early identification of potential unsuccessful students. Variations of the Rough Set approach are evaluated to determine the one most suited for the particular dataset. The results are promising since the accuracy of student performance prediction presents an *Area under the Receiver Operating Characteristic Curve* equal to 80%. The benefits anticipated from early identification of weak and/or potentially unsuccessful students will enable educators to engage these students at the onset of the course and enroll them in additional activities to improve their performance.

**Keywords:** academic performance prediction; linear systems; rough set theory; knowledge discovery

**J. Menacho, L. González-Sabaté** 1003–1018 Testing a QFD Methodology to Improve a Calculus Course for Engineers  
**R. Tejedor-Estrada and J. Tricás**

The aim of this work is to advance the teaching quality of a first-year Calculus course through the use of a cycle of continual improvement. This requires the use of a tool that both helps to gather information on the quality achieved and to detect areas in need of improvement. The Quality Function Deployment (QFD) matrix can be used as such a tool. However, following the reviewed literature, the way in which the QFD is employed is indeed variable, and it has rarely been used for a first-year subject. We have developed and implemented a methodology based on the use of QFD matrices focused on student opinions. Our method is easily implementable by professors, and it does not require specific training, nor does it involve high costs. By means of a survey, we have collected the perceptions of the teaching quality, or lack thereof. These results have been analyzed through House of Quality (HoQ) diagrams to place a value on the specifications of the course and to identify and target those characteristics of greater importance, with the end goal being to improve quality. From this analysis, we have extracted some guidelines for improvements to be implemented. The study has been made in two consecutive years. The comparison of the two years shows that the weaknesses identified in the first year, and the improvements introduced for the second year, have created a significant increase in perceived quality. This methodological approach is useful in that it allows an evaluation of teaching quality. It helps in the determination of possible avenues for improvement, and ultimately it allows for an analysis of the evolution of perceived quality over time.

**Keywords:** first-year engineering; calculus; QFD; quality improvement

**Lesley Strawderman and Laura Ruff** 1019–1026 Designing Introductory Industrial Engineering Courses to Improve Student  
Career Efficacy

This study sought to examine the design of Industrial Engineering introductory courses with students' career outcomes in mind. Specifically, this study focuses on career efficacy, or students' perceptions of their ability to succeed in a particular career field. Syllabi were reviewed in order to gain knowledge of variations in introductory course content and structure. 231 undergraduate Industrial Engineering students in the United States completed a 41 question survey that included four parts: student information, career efficacy, course information, and course evaluations. Survey responses indicated a significant increase in career efficacy in discipline-specific courses when compared with general introductory courses. Upperclassmen also reported significantly higher career efficacy than underclassmen. Students who reported enjoying the introductory course, as demonstrated by measures of satisfaction with the course, also had higher efficacy scores. The implications of study findings on the design of introductory courses in Industrial Engineering are discussed.

**Keywords:** Industrial Engineering; efficacy; introductory course

**Desmond Adair, Martin Jaeger and** 1027–1036 Comparison of Two Approaches when Teaching Object-Orientated  
**Jonathan Stegen** Programming to Novices

It has been stated several times in the literature that novice students must grasp object-orientated concepts immediately as the fundamental knowledge for programming using Java. Also, that introducing students to programming using the simpler procedural concepts early only compounds the difficulty of teaching object-orientated programming, as the need to always use some aspect of object-based code in Java cannot be avoided. Attempting to disguise this eventually causes frustration and confusion, even for good

students. This paper presents the results of a comparison that evaluates, using a pre-test–post-test control group design, two approaches to teaching Java, where one approach uses objects first and the other uses a procedural followed by an objects approach. The results of the empirical study indicate that the students, who were first year engineers, using the objects first approach do indeed gain a better understanding of programming. This finding is supported by information gathered from a debriefing questionnaire, where the objects first approach was rated as easier for acquiring Java programming knowledge and skills.

**Keywords:** object-orientated programming; learning effectiveness

**Frederic Segonds, Nicolas Maranzana, Philippe Veron and Ameziane Aoussat** 1037–1045 Collaborative Reverse Engineering Design Experiment Using PLM Solutions

The current climate of economic competition forces businesses to adapt to the expectations of their customers. To achieve this, in spite of the increasing complexity of mechanical systems, it becomes necessary, amongst other things, to reduce design time. Faced with new challenges, practices in design training must evolve to allow students to be mindful of these evolutions as well as to be able to manage projects in these new work environments. After presenting a state of the art of collaborative tools used in product design, our paper presents an experiment focusing on the reverse engineering of a complex mechanical product. This experiment was carried out between two centers of the Arts et Métiers ParisTech School of Engineering, located in Paris and Angers. We analyze the results obtained in this experiment and propose a collaborative environment that is well suited to our needs for design education, based on “Product Lifecycle Management” (PLM) concepts. Finally, we present some modifications in collaborative design courses for our students, and we implement network modifications in order to significantly improve the ease of use of the design environment.

**Keywords:** reverse engineering; education, PLM; collaborative design

**S. Wandahl, W. Olsen and L. F. Ussing** 1046–1053 Relevance of Academic Internship to the Quality in Construction Management Education

Aalborg University, Denmark, has for a decade run an M.Sc. course in Construction Management in the Building Industry in compliance with the university’s general mode of study: Problem Based Learning, project organisation and group work. Recently the programme was reviewed based on questionnaires completed by graduates and their superiors, and guided interviews. The review included the third semester’s optional internship. The internship is designed to combine practical and academic learning within the semester theme: Innovation. A comprehensive report documents the learning. This paper describes the findings and recommendations of the review for this internship. The overall conclusion is that the internship creates added value for the students, and thus either optional or compulsory internships should be incorporated in future programmes. The industry advances a positive stance towards internships. Some of the weaknesses of internships are pointed out, e.g. the preparedness of the companies and the academic level of the students’ internship report.

**Keywords:** construction management education; problem based learning; internship; project orientation; co-operation

**Philip Ciufu** 1054–1060 Analysis of First-year Student Performance in an Engineering Program

During the last ten years, the typical criteria for entry to an engineering course at a university in NSW, Australia, has been based on the University Admission Index (UAI). It was an index derived largely from the achievements of a student in examinations at the end of their secondary school education. The UAI provided a measure of overall academic achievement that assisted institutions to rank applicants for tertiary selection. In 2010, the UAI in NSW was replaced by the Australian Tertiary Admission Rank (ATAR). A student who is able to rank well enough, will be able to enter an engineering course of their choice without any further testing of cognitive ability. Students who are unable to achieve the desired ranking will need to find alternative methods of entry. The question of just where this ranking cut-off lies could be regarded as a subjective measure; is it possible that universities are denying entry to students who have potential to become successful engineers? In this paper, an analysis of the performance of a group of students who have completed their first-year of study in electrical engineering at the University of Wollongong during the years 2000–2010 is undertaken. Student groupings are created based on their background knowledge and their performances investigated. The result is a collection of results that illustrate the likelihood of a student achieving an acceptable result at the end of their first year of study.

**Keywords:** predicting performance; comparative performance; engineering education; entrance criteria

**Yanfel Liu and Carlos Pomalaza-Ráez** 1061–1071 Freshman Engineering Project on Energy Scavenging

This paper describes the design, development and implementation of an energy scavenging project for an introduction to engineering course. The overall objective of the project is to provide students with a hands-on experience on all the components of a renewable energy system. After completing this project students should be able to understand the basic engineering concepts as well as the principles of the design process. Energy scavenging is a form of renewable energy technology at micro or nano scale level. In this project students design and build a small vibrating system that takes the place of the energy source. A piezoelectric material is used to collect the energy produced by the vibrating system. The output of the piezoelectric material is fed to a rectifier circuit whose output charges a battery. Over two hundred freshman engineering students from four different disciplines: civil, computer, electrical, and mechanical have completed this project. Students’ reports, reflection papers, and the results from surveys clearly show that, in addition to be a very appealing project, its objectives are achieved.

**Keywords:** freshman engineering; energy scavenging; concept learning; piezoelectric material

**Barry L. Shoop and Eugene K. Ressler** 1072–1080 Developing the Critical Thinking, Creativity and Innovation of Undergraduate Engineering Students

We present the framework of a novel upper-division undergraduate course that was developed to deliver disruptive and innovative applications of commercial technologies to an external funding agency and simultaneously develop the critical thinking, creativity and innovation of undergraduate engineering students. The course is structured as a deliberate interactive engagement between students and faculty that combines the Socratic method with the Thayer method to develop an understanding of disruptive and innovative technologies and a historical context of how social, cultural, and religious factors impact the acceptance or rejection of technological innovation. We present an assessment of this new course based on a course-end survey, several external indicators, a post-graduation survey and faculty assessment.

**Keywords:** critical thinking skills; creativity; innovation; disruptive technology; Socratic dialog; Thayer method

**Valentina M. Nejkovic and Milorad Tosic** 1081–1093 Influence of Several Years Use of Wiki on Academic Motivation Improvement

In this paper we study the influence on students’ motivation of using wiki-based teaching and learning in academic settings over a period of several years. The goal is to improve academic motivation and stimulate more effective learning habits by accumulating knowledge and using the repository of previously accumulated knowledge. With the aim of studying the effects of several years of wiki-based teaching and learning on university students’ motivation, data are collected and analysed by means of usage logs analyses, survey-questionnaire based method, and final exam results analysis based on the data taken from faculty archive over three academic years. The case study included students on five Information Systems related courses, on average 150 per academic year. The results indicate that the adoption of the Wiki Learning System in teaching and learning process increases students’ motivation.

**Keywords:** wiki; teaching and learning; academic motivation

The purpose of this paper is to introduce the need for transdisciplinary graduate education in institutions of higher education and share the survey analysis and results with the readers. The survey was divided into four groups: research scientists, academics (faculty), industry/business persons, and graduate students. With over 134 responses, the data provided an abundance of useful information on transdisciplinary educational activities. A few items were clear in reporting the results of this survey. For example, 'Bringing together graduate students and faculty as well as researchers from diverse disciplines interested in transformative educational agendas for graduate studies through integrative transdisciplinary courses, lectures, and seminars' showed a very strong relationship to all the education objectives except the second one, namely 'To educate students broadly and prepare them for an increasingly transdisciplinary, collaborative, and global job market.' The analyses of the results suggest that individual group decisions are reasonably consistent with the entire group decision. Finally, it is concluded that the main factor, namely 'Enhancing a transdisciplinary dialogue between disciplinary courses,' is almost an exact match with all the groups' rankings and relationships.

**Keywords:** transdisciplinary education; international perspective

Despite the importance of engineering, young students in Korea are not exposed to a proper engineering education until they enter college to major in it. This situation leads to difficulty in recruiting talented students to colleges of engineering. In this paper, we first review various youth engineering programs in the UK and US. Next, we present the design and implementation of a youth engineering adventure program (YEAP) for Korean students. Most young people who participated in YEAP were satisfied, and they responded that their interest in engineering increased. We expect that YEAP can eventually contribute to national industry development by increasing young people's interest in and enthusiasm for engineering.

**Keywords:** youth engineering education; engineering experience program; YEAP

Despite decades of research on and efforts to increase the low numbers of women in engineering in many parts of the world, underrepresentation persists. This paper analyzes recent engineering education scholarship to determine what reasons are given to explain why underrepresentation is a problem, in other words, how underrepresentation is problematized. Using discourse analysis as the theoretical lens, and drawing on prior research that employed similar methods and theoretical perspectives, this paper examines an international dataset of engineering education journal articles and conference proceedings from 1995–2008. Four categories of problematizations are identified and discussed in order to advance critical reflection that could be beneficial in moving forward discussions about underrepresentation.

**Keywords:** discourse; gender; problematization; underrepresentation; women in engineering

This paper presents two complex systems of automatic control and measurement as an example to demonstrate the effectiveness of remote laboratory. One platform presents control and torque measurement of a stepper motor and the second model illustrates pumping station with two water tanks and pumps. Both remote control systems allow users to access the real-time data, make implementation using PLC/HMI (Programmable Logic Controllers/Human Machine Interface) controllers and build SCADA (Supervisory Control and Data Acquisition) visualization software to monitor and manage the control process. Presented systems are used on the experimental laboratory education on Chair of Computing Engineering at Poznan University of Technology in Poland. The author presents the philosophy and methodology of using approach, including the implementations details and his experience in using it. The objective is to present remote laboratory kits for teaching and learning some aspects of control systems. Additionally, the security policy that provides multiple access is described and the effectiveness of the platforms in educating students is discussed.

**Keywords:** programmable logic controller (PLC); stepper motor; remote access laboratory; supervisory control and data acquisition (SCADA)

Students currently learn theoretical concepts about Electronics in class sessions and then go on to work in a laboratory. Usually, when they arrive to the laboratory they have insufficient knowledge about the relation between theory and practice and also measurement instruments operation. As a result, component damage is common during laboratory sessions. This paper introduces ISLE (Integrated Self-Learning System of Electronics), an integrated learning system for students to use as a self-assessment tool. The objective is to improve the students' knowledge about the relations between theory and practice and to prepare them to work efficiently in the laboratory. ISLE combines a hypermedia book with a virtual laboratory and a multimedia test tool. It follows the constructivist theory and constitutes an interactive computer-based complex tool enhancing competence based learning. The system was tested in a first course on Electronics. Four groups of students took part: two groups used ISLE and the other two groups did not. Having observed some differences in the means of both groups, a statistical comparison was conducted using SPSS. To compare the averages, a variance analysis (ANOVA for one factor) was carried out using Tukey contrast. The observed differences are significant.

**Keywords:** self-learning system; virtual lab; self-assessment

A computer-based training tool has been developed for the Signals and Systems undergraduate course for students. It consists of an automatic problem generator and an automatic self-assessment system that can be used by the students as many times as they want. The students use the tool to generate a numerical variation of a problem, solve it, and use the tool again to answer a series of questions that are automatically assessed. The proposed problem comprises the continuous-time-domain characterization of a linear and time invariant system and its Fourier and Laplace domain analysis. The tool was used during the academic year 2009/2010 by a group of 19 students, and their grades in a final exam were compared with those of a similar group of 17 students who did not use the tool. On a 0–10 scale, the mean and standard deviation of the grades of students who used the tool were 6.5 and 1.8, respectively, whereas the mean and standard deviation of the grades of the student who did not use this tool were 5.1 and 2.6, respectively. The analysis of variance of both sets of marks yields to a  $p = 0.05$  value. The tool can also be used by the teacher as a computer-based assessment system.

**Keywords:** computer-based assessment; automatic problem generation; self-learning