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Contents


Ahmad Ibrahim 1835 Editorial

Ning Fang, Oenardi Lawanto, Wade Goodridge, Idalis Villanueva and Kurt Becker

This paper describes a U.S. National Science Foundation-funded Research Experiences for Undergraduates (REU) Site program that aims to provide undergraduate students with experiences in engineering education research (i.e., education research in the context of engineering). This paper provides an overview of the program and briefly describes the common intellectual focus of this REU Site program. Over the past two years, a total of 16 undergraduate students, seven graduate mentors, and five faculty mentors have actively participated in the program. Four important components of the program are described in this paper, including student recruitment and selection, REU seminars, weekly reflections, and REU research projects. The results of the project evaluation show that the program has made a positive impact on increasing education research skills and communication skills of the participating REU students. Eighty percent of the participating REU students reported that the research projects they worked on increased their motivation and confidence for continuing to engage in engineering education research.

Keywords: Research Experiences for Undergraduates (REU); REU Site program; engineering education research; self-regulated learning

Anastassios Kozanitis and Jean-François Desbiens

A recent transition to an outcome-based engineering education in Canada has prompted changes to instructional and pedagogical methods. Given that students can express a different degree of motivation depending on the course and on the learning activities within a course, there is a need to examine the motivational dynamics that drive the students in the learning process. Moreover, most studies on engineering students’ motivation have examined motivational components independently. The purpose of this study is to analyze the joint contributions of student characteristics, their perception of instructors’ attitudes and behavior when interacting with students, as well as their perception of the nature of the learning activities and their impact on student motivation within a course. The sample was composed of 215 students attending a francophone engineering school in Canada. Participants completed a questionnaire composed of 42 items from various existing instruments. Multiple linear regression analysis was used to predict the set of motivational components for this study. Instructors’ attitudes and behavior, as well as higher-order cognitive tasks are significantly related to student motivational components, resulting in a positive impact on mastery goal, performance goal, task value, control beliefs, and self-efficacy.

Keywords: motivation; teaching methods; student-centered

J. C. Cuevas-Martinez, A. Triviño-Cabrera, M. D. Molina-González and A. J. Yuste-Delgado

This paper reports the results of a two-year experiment in which competitiveness and collaboration were employed to support university students in their learning process, with the intention of simultaneously improving their motivation, teamwork, initiative and resolution. The main novelty of the designed framework is that it is composed of two tiers: Global competition in all subject areas and a short-term competition associated with the lab sessions. The short-term competition can help them balance their workload. A total of 167 students of engineering participated in this study. The results show that the approach was beneficial to the students.

Keywords: student motivation; higher education; competitive learning; collaborative learning

Nichole Ramirez, Sally Smith, Colin Smith, Tessa Berg, Beata Strubel, Matthew Ohland and Joyce Main

Cooperative education programs (co-op) play a vital role in developing engineering and computing students’ applied technological skills and professional self-confidence. Nevertheless, not all students choose to participate in co-ops. Through empirical data collection undertaken at two universities, this article explores students’ perceptions about co-op programs and why some students do not participate in optional co-op programs. The 408 participants were in one of three groups: (a) co-op participants, (b) interested applicants and non-applicants, or (c) those not interested and/or did not apply. Using Rational Choice Theory as an interpretive framework, quantitative and qualitative analyses of surveys and interviews were used to compare and contrast experiences, approaches, motivations and attitudes across student groups in the United States and the United Kingdom. Results show that US and UK students who identified as not being interested in co-op shared similar perceptions, including the perceived cost of additional time to graduation. Students also expressed concern that taking time away from campus to complete a co-op would affect social interactions with their peers. The results of this work can be used to inform co-op program processes and policies, highlighting ways in which programs can increase participation. The study also shows how key stakeholders can learn cross-cultural ‘best practices’ to make co-op education accessible and effective.

Keywords: cooperative education; perceptions; student pathways; computing; engineering
Persistence of undergraduate engineering students has long been a challenging issue in many engineering programs at higher education institutions in the United States (U.S.). Although much research has been performed to study factors affecting student persistence, research findings vary from institution to institution due to cultural and other unique differences at each institution. The present research adds to the knowledge base by employing readily available institutional data to determine factors affecting persistence of engineering undergraduates at a public research university in the U.S. Institutional data collected on declared engineering majors were sorted into equal-sized groups of 383 persisting students and 383 non-persisting students, totaling 766 students. Statistical t-tests were performed to analyze numerical (continuous) data that correspond to four factors: high school GPA (graduate point average), ACT (American College Testing) math score, composite ACT score, and projected age at graduation. Statistical Pearson’s chi-squared tests were conducted to analyze categorical data that correspond to six other factors: gender, race/ethnicity, first-generation status, academic major, marital and financial aid status. Results of statistical analysis show that students with higher high school GPAs, ACT math scores, or composite ACT scores were more likely to persist in engineering. Older or married students were also more likely to persist than younger or single students. When compared with in-state resident students, out-of-state resident students were less likely to persist, and international students were more likely to persist. Students who had received financial aid were more likely to persist than those who did not. These research findings have practical implications. Higher education institutions can adjust entrance criteria to increase the chances of success for students admitted into engineering programs.

Keywords: persistence; undergraduate engineering students; institutional data; quantitative research

Linda Stern, Colin Burvill, John Weir and Bruce Field
1888–1902 Metrics to Facilitate Automated Categorization of Student Learning Patterns while using Educational Engineering Software

In this paper we describe the use of metrics for analysing student interactions with educational software. We applied this metric-based approach to a class of 200 second-year undergraduate students using an educationally-oriented software simulator to solve specific problems in mechanical engineering design. Our results show that a metric can facilitate categorization of student learning. We suggest how similar metrics could allow automated focusing on feedback to learning on both teachers and students. Since it is based on numerical analysis and modelling, our approach is particularly well-suited to software used to support teaching and learning in engineering and other mathematically-based disciplines.

Keywords: learning analytics; technology for learning; mechanical engineering education; audit trails

Nissim Sahag and Elena Trotskoysky
1903–1910 An Examination of the Relationship between Instructional Strategies to Learning Styles Distance and Students’ Achievements

Some researchers claim that a close match between a student’s learning style (LS) and the teacher’s instructional strategies (IS) supports students’ achievements. Accordingly, in order to maximize student achievements, teachers should adjust their teaching strategies to fit their students’ learning styles. The current paper deals with a true field experiment aimed at examining the relationships between the distance of teachers’ IS to students’ LS and students’ learning achievements. An IS-LS distance for each student and his or her teacher was measured, and its correlation to this student’s achievements was calculated. The Felder-Soloman Index of Learning Styles (ILS) was used to measure students’ preferred LS as well as teachers’ preferred IS and a method for measuring the IS-LS distance was developed. The research population, comprising 165 students and 8 teachers from one high school and two colleges, completed the ILS questionnaire. The absolute value of the difference between the student’s LS and teacher’s IS defined the IS-LS distance; the distances were calculated for each student and the relevant teacher. If the argument that a good IS-LS match contributes to a student’s achievement is valid, then a significant negative correlation between the IS-LS distance and the student’s achievements must appear. The correlations between the IS and LS distances and students’ achievements in 17 courses were calculated in order to answer the above question. The research findings do not support the assumption that matching IS to LS improves student achievements.

Keywords: engineering education; instructional strategies; learning styles

A. Cervone, J. A. Melkert, L. F. M. Mebus and G. N. Saunders-Smiths
1911–1921 Push or Pull Students into Blended Education: a Case Study at Delft University of Technology

Blended education, or “flipping the classroom” is rapidly becoming a mainstream form of teaching within universities. Within Engineering Education, it is popular as it allows more time in-class to focus on hands on activities such as demonstrations and solving complex problems. This paper discusses the effort conducted to re-structure, according to the blended learning principles, the “Propulsion and Power” course of the Aerospace Engineering Bachelor degree programme at Delft University of Technology (TU Delft). The redesigned course was supported by a dedicated online & blended education unit within the university, and is characterized by a very peculiar structure due to the different approach chosen by the two involved lecturers. The first lecturer decided to “pull” the students, by proposing a number of additional videos available in the World Wide Web as a support and complement to the material taught in class. Conversely, the second lecturer opted for a “push” approach, self-recording theory videos to be watched by the students at home and devoting the in-class hours to exercises and applications of the theory. This format resulted in a clear improvement of the average exam grades and pass rates. The student feedback showed enthusiasm about the new blended course, with only a very small minority still preferring the previous, more traditional approach. Although there seems to be a slight preference of students towards the “push” strategy, the “pull” approach has also been widely appreciated. However, the objective to re-attract students to the contact hours in class was only partially achieved, since just a slight improvement in the number of attending students was observed. This paper clearly shows that the efforts to implement a blended teaching strategy has great benefits for both students and staff alike.

Keywords: blended learning; online education; student engagement; electronic assessment; aerospace engineering

Fabricio Kurman Merlin, Vera Lucia Duarte do Valle Pereira and Waldemar Paccheco Junio
1922–1934 Applying Piaget’s Equilibration Theory to Understand Conceptual Learning in Engineering Education

Conceptual learning bridges the novice-expert gap, enabling transfer of structured knowledge to develop skills for new situations in engineering for both technical and humanistic domains. Though substantial information about expertize development is already available to support teaching in engineering, it is directed largely ascertaining characteristics or status of novices and experts and lacks emphasis on cognitive mechanisms responsible for bridging or transposing from one behavior status to another. Thus, this article explores the cognitive mechanisms stimulating engineering students’ conceptual learning under Piaget’s equilibration theory, which addresses the main problem of knowledge construction. In order to discuss Piaget’s equilibration theory usefulness for the conceptual learning process, we present a study case where we tracked the progress of 18 engineering students enrolled in ‘Introduction to Engineering’, over two semesters. In this humanistically-oriented course, freshmen are challenged to theoretically connect Science, Art, Technology, and Engineering concepts in order to stimulate critical thinking skills. We gathered data through semi-structured interviews, applying Bardin’s content analysis techniques. The discussion of the results provides an interesting view of the utility of Piaget’s theory in engineering education in humanistically-oriented courses as an alternative to focusing on transformations in conceptual learning.

Keywords: genetic epistemology; equilibration theory; conceptual learning; engineering education; higher education
This study investigates electrical engineering students' engineering epistemological beliefs by using the Chinese version of the Epistemological Beliefs Assessment for Engineering (CEBAE). We recruited 468 electrical engineering students from two research-based universities in Taiwan. Prior to the study, confirmatory factor analysis and reliability testing involving 188 engineering students were performed to evaluate the validity and reliability of the CEBAE. The results revealed that Taiwanese engineering students in research-based universities had only slightly sophisticated engineering epistemological beliefs. Students' educational backgrounds influenced their engineering epistemological beliefs. As the grade level progressed, students' engineering epistemological beliefs became more sophisticated (with the exception of the third year). Male engineering students exhibited significantly more sophisticated engineering epistemological beliefs compared with their male counterparts.

**Keywords:** engineering epistemology; electrical engineering education; engineering philosophy


Government agencies and professional organizations are calling for changes in engineering, science and math education. In response to these calls for change, engineering education scholars are undertaking a variety of investigations of change within engineering education, including studies of instructional practices and the factors that influence choice of instructional practices. This paper provides a detailed description of the development and implementation of three quantitative methods to characterize instructional practices within engineering undergraduate programs. The three methods are: analysis of course syllabi, a student survey, and a faculty survey. For each method, the development and implementation processes are described including major challenges that were encountered and how they were addressed. Data are presented for one program in order to illustrate the types of results that are derived from each method and the types of conclusions that can be drawn from the combined data set. The overall goal of the paper is to provide sufficient detail to allow other engineering programs to adopt, or adapt, the methods to undertake studies of instructional practices. The coding scheme for the syllabi analysis and copies of the items used in the student and faculty surveys are included in appendices of the paper.

**Keywords:** research-based instructional practices; assessment; teaching practices; educational improvement


After more than a decade of efforts to enhance the quality of engineering education research, including assessment development, it is timely to explore what types of validity evidence are frequently reported in assessment research articles. According to the Standards for Educational and Psychological Testing, the foundation of quality assessment rests on evidence of reliability, validity, and fairness. The purpose of this study was to explore what aspects of reliability, validity, and fairness evidence are provided in assessment instrument development publications in major engineering education journals since 2005. Using quantitative content analysis, the authors reviewed twenty-nine articles published in four major engineering education journals between 2005 and 2015. A coding scheme, based on Messick’s Unified Theory of Validity and the Standards for Educational and Psychological Testing was developed to code the aspects of reliability, validity, and fairness provided in each article. Frequencies for each code are reported. Engineering education articles on instrument development most frequently reported evidence related to aspects of internal reliability, content-related validity, and substantive aspects of validity. However, studies of generalizability, consequences, and fairness were largely void. In addition, reliability was most frequently studied through internal reliability coefficients, while other forms, such as test-retest were less frequently reported.

**Keywords:** validity; instrument development; assessment; measurement; reliability; fairness


Engineers iteratively apply their disciplinary knowledge to develop solutions to ill-defined problems considering varying and often competing criteria and constraints. Design is a process engineers use to solve ill-defined problems necessary to fulfill human needs. While worldwide institutions are increasingly introducing engineering design in undergraduate engineering education, the extent of integration of design into the curriculum occur at varying degrees. In this study we focus on a higher education institution in Colombia through a single case design. We specifically evaluated the effect of a workshop designed to introduce engineering design to engineering students in a context where there have been limited initiatives and resources to introduce engineering design. Two groups of students from different engineering programs in a public university in the Colombian Caribbean region participated in an eight-hour workshop. The workshop involved a design challenge of creating a net-zero energy house using a CAD tool. The two groups were comprised of 20 systems engineering students and 25 industrial engineering students. Pre- and post- instruments were collected and analyzed to assess the effect of the workshop on students’ understanding about engineering, disciplinary knowledge, and effective practices of engineering design. The results suggest that the design workshops employing CAD simulations can support engineering education in three ways by: (1) broadening student knowledge about the engineering practice; (2) fostering the acquisition disciplinary content knowledge; and (3) increasing student proficiency regarding engineering design.

**Keywords:** engineering design; Colombia; CAD; Energy3D


This study seeks to explore the implementation of design swapping to encourage students to document their designs. Design swapping involves having teams swap design sketches shortly after a design review such that they construct another team’s design. Teams are incentivized to document their designs through sketches because other teams build their designs. This study seeks to investigate the effects of the timing of notification of students on the overall review quality of design sketches in the setting of an engineering summer camp for middle and high school students and student perceptions of the design swapping activity. Data sources included design sketches, design sketch quality scores, and individual reflective survey question responses. A total of 136 middle and high school students participated in the study, split across 39 teams at 8 different sites. Data were analyzed using descriptive statistics, repeated measures ANOVAs, and thematic analyses. Results showed that students who were notified prior to a design review of an imminent design swap generated higher-quality design sketches than those who were not notified or notified after a design review. Some participants saw design swapping as a positive opportunity for growth and real-world engineering experience, while others found it challenging. Design swapping is a viable pedagogical strategy to encourage students to generate higher-quality design sketches, and provides students with a surrogate client in the absence of a real client.

**Keywords:** pre-college design; design sketches; design quality; swapping sketches; STEM
Patent system has an important role in engineering design process as it provides a source of ideas through patent information. On the other hand, the patent system poses potential constraints on the engineering design process, because a granted patent in force may prevent the exploitation of a technical solution. The aforementioned issues are the main reasons why the patent search should not only be performed as a search for ideas and a search for potential constraints on the innovation process, but also be taught in engineering design courses. Namely, in order to be able to carry out their future tasks in industry, engineering students need to be capable of handling patent information since it strongly influences any industrial innovation process. The existence of information, however, does not guarantee its proper usage, since patent search requires considerable knowledge and effort by the searcher to access and benefit from the information contained in patent databases. For this reason, we developed an invention representation and reasoning scheme based on engineering design artefact models in order to improve the quality of patent search process, primarily among non-experienced researchers, such as engineering students who typically use patent information as a source of ideas in engineering design and product development projects. The invention reasoning scheme contains categories adopted from the theory of technical systems, primarily the model of transformation process and the model of technical system, as well as categories from other Workshop Design Konstruktion (WDK) theories, and is aimed at supporting reasoning during the patent search process. In order to investigate the applicability of such a scheme in patent search, a case study on a small group mainly consisting of mechanical engineering students was conducted, which demonstrated that this patent search reasoning tool based on the WDK artefact models may be successfully applied in patent searches conducted by non-professional patent searchers.

**Keywords:** patent search; engineering design; artefact models

### Engineering Creativity: Toward an Understanding of the Relationship between Perceptions of Creativity in Engineering Design and Creative Performance

Few studies have focused on perceptions of engineering students with respect to the importance of creativity in engineering design. Previous researchers have tended to focus on perceptions concerning the degree to which creative thinking is emphasized in the classroom, rather than on whether students value creativity as an important part of the engineering design process. Moreover, the relationship between students’ perceptions of the importance of creative thinking in engineering design and their creative perceptions has not been investigated. The purpose of this study was to identify engineering students’ perceptions of creativity during the engineering design process and compare perceptions of students who scored at the extreme ends on a creativity test called the Creative Engineering Design Assessment (CEDA). Of the 42 students that took the CEDA, eight students scored at the extreme ends and were subsequently interviewed. The perceptions that were investigated reflected the two primary influences on a students’ motivation to be creative as posited by the expectancy-value theory, namely engineering students’ perceptions of the importance of creativity during the course and their expectations of their own abilities to be creative in engineering design. The findings of this study support predictions made by applying the expectancy-value theory, which holds that students who value creativity in engineering design and confidently believe they have the ability to be creative are more likely to be creative in various engineering design scenarios.

**Keywords:** creativity; engineering design; perceptions; expectancy-value theory; mechanical engineering

### Developing Practical Abilities through a Teaching Reform of Tissue Engineering Course

This work describes a teaching reform of Tissue Engineering course that designs a laboratory course for senior undergraduate students, where students are challenged with a real-life tissue engineering application and provided with a hands-on experience applying oriented biomaterial technology and cytotecnology by conducting an experiment. Forty senior undergraduate students coming from School of Biological Science and Medical Engineering in Beihang University attended the course. The laboratory course was designed to guide students in raising research questions, generating strong hypotheses, identifying appropriate methodologies, and collaborating with each other to solve problems. Feedback from students attended this course has indicated that, while students find the expectations challenging in the early stages of the course, finally they are able to increase awareness and deepened their understanding of this field. We hope that this kind of educational modality could spread out to other interdisciplinary fields and contribute to the fast development of modern interdisciplinary science and technology.

**Keywords:** interdisciplinary field; tissue engineering; laboratory course; practical abilities; undergraduate students

### ICT Entrepreneurial Ecosystem for Engineering Education

Entrepreneurship is a powerful route to integrating skilled people into the working market. However, its teaching is particularly weak in engineering degree programmes. The objective of this innovative action has been to develop an entrepreneurial ecosystem to improve ICT entrepreneurial skills at engineering universities of countries with weaker entrepreneurial tradition in new technologies. An acceleration programme has been designed for engineering students with the objective of creating start-ups, going beyond the concept and becoming a start-up in early stage. Innovative methods have been used to create and accelerate start-ups within an entrepreneurial ecosystem adapted to the university context. For four years of experience (2012–15) have allowed us to collect indicators and improving the proposed methods to scale up the model to the wider EU. Two hundred sixty-one students have participated in this experience and fifty-six start-ups have been created. Of those, thirty-eight have successfully finalized the programme.

**Keywords:** interdisciplinary projects; cooperative learning; engineering education; IoT
In our review we examined the primary and secondary influences of mechatronic experiences on student engagement in fundamental engineering courses. Using a systematic review methodology, we collected 402 articles with publication dates ranging from 1990–2014. Screening on title and abstract information reduced our included sources to 137, from which we mapped six parent and 22 child codes. Appraising 17 of these articles we identified eight high quality studies as the focus of our synthesis, which identified five primary influences (Student Motivation, Self-Efficacy, Course Rigor, Learning Retention, and Gender) and two secondary influences (Accreditation and Ease-of-Implementation). In these influences we found evidence that mechatronic experiences can improve student motivation, self-efficacy, and course rigor. Also, positive effects on learning retention, gender diversity, accreditation efforts, and ease of course content implementation were identified. Future research is needed to clarify: (1) how mechatronic experiences impact student motivation and self-efficacy more than lecture-based strategies, (2) how the positive short-term impacts of these experiences translate to subjective academic success (i.e., future course and career goals), (3) how implementation logistics are influenced by experience type (i.e., open-ended projects versus contests), class size, institution and industry support, etc., and (4) to what degree the factors of gender, underrepresented student groups, course curricular placement, and activity type influence student engagement.

Keywords: student engagement; mechatronics; problem-based learning; project-based learning