Volume 33 Number 1(A) 2017 ISSN 0949-149X

The International Journal of Engineering Education

Contents

Contributions in: Active Learning, Innovation, Creativity, Engineering Identity, Science Fair, E-Learning, Moodel Tools, Virtual Laboratories, Mobile Computing, Technology Acceptance Models, Liberal Arts Graduates, Reading Abilities, Non-Technical Coursework, Course Structure, Accreditation, Academic Performance, Assessment, Conceptual Understanding, System Thinking, Control Systems, Dynamic Systems, Computer Science, Advanced Manufacturing, Statics, Civil Engineering, Electrical Engineering

Engineering instructors' adoption of active learning has been slow, despite significant evidence supporting its efficacy. A common instructor concern is that students will respond negatively. This study measures the relationship between student response to instruction and 1) students' expectations for types of instruction, 2) students' experiences of different types of instruction, and 3) instructor strategies for using in-class activities. Student Response to Instructional Practices (StRIP) survey data from 179 students at three U.S. institutions were analyzed using hierarchical linear regression modeling. Significant predictors in the final models of student response were student expectations of active learning lecture and passive lecture, experiences of group based activities, and instructor strategies for explaining and facilitating active learning. These empirical results support recommendations in prior literature about best practices for reducing student resistance and demonstrate that instructors have great power to influence student reactions to active learning and ultimately reduce student resistance. There was no evidence in this data set to support the common concern that instructor or course evaluations are negatively affected by adopting active learning strategies.

Keywords: active learning; instructional methods; engagement; regression modeling

Over the past four years, fifty-three peer-nominated engineering innovators were interviewed about the process of creating innovations and the personal characteristics of engineers who do so successfully. These interviewees were drawn from across all engineering disciplines and all types and sizes of organizations where they were employed. Our main objective was to better understand the behavioral characteristics that lead engineers to discover, develop, and implement innovations in products, processes, or concepts. We call this behavior engineering innovativeness. This paper describes our rigorous process for discovering the essence of *engineering innovativeness* and its characteristics. As portraits of engineering innovativeness, we present 10 unique personas of engineering innovators gathered from our interviews. Identifying the behavioral characteristics of innovative engineers and their personas is important to both the education of student engineers and the professional development of practicing engineers. If engineers are expected to behave in an innovative manner in their academic and professional endeavors, then understanding the behavioral characteristics and personas of 'expert' or 'master' innovative engineers is an essential first step in learning to behave in an innovative manner or to become more innovative as an engineer. We discovered that there is not one type of engineering innovator or a single group of characteristics that define engineering innovativeness; rather, there are many different types of engineering innovators, as evidenced by the unique groupings of engineering innovativeness characteristics identified by our experts.

Keywords: personas; engineering; innovativeness; innovators

As an emerging new interdisciplinary area, biomedical education has been recently paid a growing attention to its curriculum design. Creativity has been suggested as a key element in its pedagogy development. This paper will focus on a research question: how do the senior teaching and research staff conceptualize 'creativity' in relation to their daily working experience and based on such conceptualizations, what are the implications for pedagogy development in biomedical education? Theoretically, we will take a departure from social-cultural approach to creativity that emphasizes shaping roles of environmental influences on creativity in a specific context of interdisciplinary teaching and learning, such as biomedical education. An empirical study by qualitative interviews (n = 15) with senior research and teaching staff at different Spanish institutions will further help to provide evidence that guides to answer the research question. The data analysis shows that creativity should be an essential element in curriculum and there are needs of creativity training programmes in biomedical education. Meanwhile, pedagogical changes should be towards encouraging collaborative work, critical thinking, problem solving by creative problem-based learning scenarios, promoting autonomy in applicable and useful projects, working with creative articles in their specific field with students, fostering students' skills in experiment design at university, and developing new evaluation systems, which underpins the necessity of providing a systematic educational environment for creativity development in future biomedical education.

Keywords: creativity; Biomedical education; interdisciplinarity; staff development; learning environment

Since the word "app" was named "Word of the Year" by the American Dialect Society in 2010, the demand for education in mobile technologies has never been greater. This paper describes the experience gained while teaching mobile apps development as a subject in a Computer Science engineering curriculum for three academic years. We provide a description of the teaching and assessment processes adopted, based on a Problem Based Learning (PBL) approach and a weighted self/peer/teacher assessment schema respectively, tackling the main issues that arise when considering these methodologies. Throughout these three course editions a total of 37 students have followed the subject and instructors have given them a great degree of freedom to propose their own projects. This has led to a high degree of motivation and ambition, and it has been rarely necessary to push any additional functionality into their initial proposals. Moreover, the projects as a whole have covered not only a good sample of the most important mobile computing aspects but also very different application areas. On top of this, we have also analyzed the implications of introducing peer- and self-assessment components into the evaluation system. In this respect, we have concluded that not only peer- but also self-assessment can be acceptably close and correlated to the marks given by the teachers. We believe that our observations, results and experiences could be useful in inspiring other teachers when designing other higher education courses (or parts of them), especially those sharing the basic characteristics of those described in this work.

Keywords: mobile computing; problem-based learning (PBL) methodology; teamwork; peer-assessment; self-assessment

This study presents the technology acceptance model to assist universities in predicting the behavioral intentions associated with the use of a human computer interface system for learning. A total of 41 students responded to a survey following the completion of an eight-week teaching course. Data were collected to examine the path relationships among all variables (perceived usefulness, perceived ease of use, attitude toward use, and behavioral intention to use) influencing the acceptance of the system learning. The partial least squares method was used to test the measurement and the structural model. Path analysis verified that acceptance of the human computer interface system was directly influenced by the learner's "attitude toward use" and "perceived usefulness." Rich content and the ease of use should be the focus when designing systems for university students, due to their effects on the behavioral intentions of students.

Keywords: technology acceptance model; human computer interface

Based on previous research on technology acceptance models, the purpose of this study was to examine the effect of four variables (perceived ease of use, perceived usefulness, output quality and enjoyment) on students' intentions to use Google Drive Spreadsheet and Arquimedes software for budgeting and measurement purposes in the Building Engineering context, as well as students' preferences to use each program. A sample of 92 students received training in both programs and evaluated them. Results suggest that students prefer Google Drive Spreadsheet in the academic context and Arquimedes in the professional context. Findings also show a significant effect of perceived usefulness and output quality on usage intentions of both applications, as well as an effect of output quality on perceived usefulness. However, with respect to the rest of variables, differences were found between Google Drive Spreadsheet and Arquimedes. While in the case of Google Drive Spreadsheet perceived usefulness and output quality worked as mediators of enjoyment, and perceived ease of use had no significant effect on any variable, in the case of Arquimedes all the variables had a significant effect on usage intentions. These results suggest that when a technology is perceived as very easy to utilize, such as Google Drive Spreadsheet, the variable perceived ease of use has very little or no impact on individuals' intentions to use that technology. Findings are discussed in terms of its implications for practice and further research.

Keywords: technology acceptance models; technology usage intentions; higher education; building engineering; software application

This paper presents a new innovative curriculum model in advanced manufacturing to transform BA graduates to enable them to find good paying jobs in advanced manufacturing. The curriculum model is an accelerated one year certificate program with a total of 25 credits. The certificate program offers two tracks: technology and innovation. The certificate courses are hybrid (offered both online and face-to-face), modular (short duration courses with targeted topics) and stackable (modular courses build on each other). The design of the courses provides flexibility to students to select the modules that match their interest and abilities. An integral and important part of the program is a one-semester long industry internship that students must take to prepare them for the new career. These internships are provided by the program industry partners. The certificate program is offered at a community college to make it more affordable for the target audience. The main contribution of the paper is the design and delivery of a technical curriculum for non-technical majors: BA graduates. This poses many design and delivery challenges as discussed in the paper. The remainder of the paper presents the model in more details, its rationale, methodology, the challenges, and conclusions.

Keywords: liberal arts graduates; advanced manufacturing; curriculum design; career transformation; internships; industry partners

A recent study indicated alarmingly low results in reading competencies of Portuguese engineering students. This paper intends to evaluate if this tendency is restricted to engineering studies or if it is also present in other scientific domains. To this end, two studies were conducted using a reading screening test. In the first study, 168 students from Engineering, Health, Psychology and Education participated in an unconstrained time administration of the test. In the second study, the same test was administered in a time constrained mode to 153 students from the same scientific areas.

It is concluded that the low results obtained for engineering students are also detected in other scientific domains. A comparison between Engineering and other domains students show slight differences, although not reaching statistical significance. These results emphasize the importance for screening tests able to quickly and economically assess college student's reading ability. This study proposes a low cost, low time consuming tool for evaluation of reading competences, along with normative results for Portuguese speaking college population.

Keywords: engineering education; college education; reading abilities; non-technical skills; dyslexia

Engineers need considerable understanding of humanities and social science to serve effectively and responsibly as professionals. Undergraduate engineering education faces pressures to add technical and non-technical content and decrease total credit hours, educational costs, and time to degree. This study characterizes how discipline-based engineering programs in the United States distribute required coursework between technical and non-technical areas of study in comparison to math, chemistry, and physics programs; the results could signal consensus or disparity in educational philosophy between and among institutions or disciplines. The distribution of technical versus non-technical coursework was delineated for 103 US News & World Report top-ranked and ABET EAC-accredited undergraduate programs in chemical, civil, electrical, and mechanical engineering based on 2013 catalog requirements, as well as chemistry, math, and physics programs at the same institutions. Technical was defined as coursework in engineering, math or natural science; non-technical was coursework outside of those disciplines. Findings reveal a wide range of required technical and non-technical course loads for all disciplines. For engineering, technical requirements ranged from 62% to 86% (median 75%) of total degree; non-technical requirements ranged from 12% to 35% (median 20%). The math, chemistry, and physics degrees were more balanced between technical and non-technical requirements. Differences in requirements suggest that consensus does not exist amongst engineering educators from this sampling of programs regarding the appropriate allocation of technical versus non-technical coursework for an undergraduate engineering education, and there are substantially divergent interpretations of what constitutes adequate ''general education'' for an engineer. Additionally, students who desire more well-rounded education might select non-engineering STEM majors.

Keywords: engineering curriculum; humanities; multi-institution; social science; undergraduate; United States; quantitative

The importance of identifying mistakes in concrete design, before a concrete structure is built, requires that engineering students learn to review concrete design as effectively as possible. Although various educational approaches support developing the necessary skills, virtually no empirical study is currently available to compare the effect of a different sequence of hands-on and theory focused learning facilitation. In order to evaluate the learning effectiveness of reviewing concrete designs, experiments were carried out utilizing a pre-test/post-test experiment design with an experimental group (first hands-on, then theory) of 45 students, and a control group (first theory, then hands-on) of 109 students. Evidence was found for the assumption that a first hands-on approach increases learning effectiveness of reviewing concrete design more significantly than a first theory approach. Furthermore, the positive learning effect on students, who began the course with a hands-on approach, showed a continuing positive effect throughout the ensuing theory focused learning phase. The findings may encourage engineering educators and educational institutions to increase the learning effectiveness of reviewing concrete design by beginning the course with a hands-on focused learning approach before focusing more on the involved theoretical concepts.

Keywords: learning effectiveness; concrete structures; design review; active learning

Accreditation has been considered the principal quality assurance mechanism and an important aspect of engineering education. It provides opportunities for change in both the curriculum of the programme and the pedagogy of delivery. However, the starting point is with staff to acquire educational knowledge applicable to engineering education. It is argued that accreditation could indeed be an opportunity for a change with positive consequences for the institution, faculty, department, curriculum, academic staff, students and industry, and discusses the challenges during the accreditation process. The objective of this paper is to review the paradigm shift from teaching to learning and how adjustment of a curriculum to a particular accreditation criterion affects the stakeholders. It is acknowledged that accreditation may provide benefits in educational and organizational quality improvements as it encourages awareness of the best practices, increases public confidence and ensures institutional accountability. However, it also entails some inherent challenges such as additional costs, increased staff workload, uncertainty regarding its effectiveness and possibly organizational concerns. Accreditation creates opportunities for change; including the fundamental adjustment in the curriculum of the programme. However, a key element is staff trained to apply educational knowledge and principles for engineering education, which is usually deficient in faculty members. A successful shift in the educational paradigm needs an understanding of the rationale for the outcomes-based educational approach and philosophy as well as the concept of attributes and non-conventional pedagogy.

Keywords: accreditation; engineering programmes, engineering education

The present study aims to examine the academic profiles of industrial engineering undergraduate students among a sample group of military college engineering students (N=276) in order to determine the factors impacting academic performance; to compare student groups that were identified by course scores, and to analyse performance changes over four academic years. The study started with data collection, database creation and preparation for clustering study. A two-step clustering methodology was used for grouping courses based on academic performance and context similarities. The clustering methodology results are validated by discriminant analysis. Student movements among clusters over the four years are identified in the longitudinal cluster analysis part of the study. Results showed that there is saturated cluster structure among students which has been preserved over years. It was concluded that the importance of background knowledge and prior motivation are effective in the academic performance rather than the change in environment. Although this study is the final stage of an ongoing project in which more than twenty officers are involved, specific data collection process and the analyses are conducted by the authors.

Keywords: academic performance; longitudinal cluster analysis; military academy; EM Clustering

Student assessment of other student's work has many potential benefits to learning for both the assessor and the assessed. However, sources of peer assessment provide, quite often, subjective evidence, which can be conflicting, uncertain and even ignorant. One of the key elements to providing an overall quality assessment of a student's work derived from the assessment by his/her peers is the use of an appropriate method of combining or fusing these heterogeneous evidence sources. Since the development of the belief theory introduced by Shafer in the 1970s, many combination rules have been proposed in the literature with two main methods selected here. The first is an evidential reasoning (ER) approach, the kernel of which is an ER algorithm developed on the basis of the framework and the evidence combination rule of the Dempster-Shafer (DS) theory. It has been claimed also in the literature that Dempster's rule generates counter-intuitive and unacceptable results in practical situations, so an approach based on the Dezert-Smarandache (DSmT) theory of fusion will also be explored, in particular the PCR6 rule of proportional conflict redistribution. Results for peer assessment marks allocated by a student cohort, consisting of 20 students, during their capstone projects, and, aggregated using each of these two approaches are compared with each other and with results obtained by the more traditional Averaging Rule (AR) approach. It is clear from the findings that when subjective evidence is aggregated then the simple AR approach as the accepted combination method is in doubt. It also seems that the DS method of aggregation seems the best alternative to traditional averaging.

Keywords: evidence; capstone; aggregating; fusion

In engineering courses, exams and homework assignments are among the standard tools used to assess students' performance and comprehension of course material. However, they do not always provide opportunities to reveal whether students truly understand related engineering concepts. This paper seeks to bridge that research gap by using eye-tracking technology to observe how students solve statics problems. In a within-subject experiment, twenty participants were asked to solve nine statics problems shown on a computer display. A non-invasive eye-tracker was used to record participants' eye movements during the problem solving process. Participants were then asked to explain how they solved three representative problems. The results show that different eye gaze patterns exist between those who solved problems correctly and those who solved them incorrectly. For the specific concepts involved in solving these problems, those who correctly understood the concepts also exhibited different eye gaze patterns than those who did not. We also found that students' spatial visualization skills positively correlate with their performance when solving statics problems. This investigation showed that eye gaze data has the potential to serve as a diagnostic tool to discern how students solve statics problems and understand related engineering concepts. These results may provide insight into students' problem-solving strategies and difficulties, and help instructors choose more adaptive teaching methods for students.

Keywords: statics; problem-solving; concept inventory; eye-tracking

In many knowledge domains, the transition from novice to expert has been characterized by changes in knowledge structure. Researchers have utilized a broad range of quantitative techniques and tools to investigate such changes. This study uses exploratory factor analysis on Statics Concept Inventory (SCI) data collected from 95 practicing civil engineers to explore their underlying, unobservable traits of basic statics concepts and compare to these from over 1300 students' data. In comparison to students' responses, the analysis of the engineers' data yielded a different number of underlying latent traits and different loading patterns of the SCI items on each trait. The four-factor model resulted in a Cronbach's alpha value of 0.84 for the whole scale, and 47.6% of total variation explained in the original set of SCI questions. Engineers' data cluster around three student factors, Free Body Diagram, Newton's Third Law, and Representation, and the SCI questions were loaded in these factors based on the 3D geometric features of the bodies. Engineers' responses to the SCI may reflect the conceptual coherence associated with knowledge of engineering practice. The engineers' combination of discreet concepts into broader concepts in this study might suggest the evidence about experts' characteristics in processing, organizing, and storing knowledge in different chunks than novices. Understanding experts' knowledge structures will help inform the development of curricular materials and assessment instruments for undergraduate engineering education.

Keywords: statics concept inventory; factor analysis; novice expert differences; engineering education

Engineers Without Borders-USA (EWB-USA) developed the Planning, Monitoring, Evaluation and Learning (PMEL) framework to confront the complex challenges inherent in international community development projects. The first critical step of the PMEL framework requires thoughtful exploration of ''pathways'' to community change: a series of proposed actions that lead to a set of positive outcomes within the community. In this study, we investigate the benefit of using Group Model Building (GMB) as a way to improve the outcome of brainstorming sessions, a key aspect of team decision making within this first step of the PMEL framework. Here we posit an important mechanism for an improved outcome in brainstorming sessions would be a shift in student mental models towards system thinking. In order to assess the value proposition of GMB in project decision making, a two-session GMB workshop was held with a EWB-USA student team working on a rural water project in Peru. A mixed-methods approach was used to extract and analyze participant mental models before and after the workshop to measure growth in systems thinking. The results of the study indicate compelling shifts in participants' mental models towards those of systems thinkers, including an understanding of important factors and how they influence as a system to impact project sustainability. Marked changes in project planning action items were also observed along with an alignment of their proposed change pathways. Overall, the project team gained a more complete understanding and appreciation of project complexity and of the factors that contribute to project success. Thus, GMB provides a useful technique to teach engineering students systems thinking, while possibly improving the quality, and thus sustainability, of EWB community development projects.

Keywords: systems thinking; Engineers Without Borders; PMEL framework; group model building; system dynamics modeling

Probing students' conceptual understanding and misconceptions of key engineering concepts is a rich area of research. Given the importance of modern electronics in today's world, it is essential for many engineers, particularly device designers from electrical engineering, to have a robust conceptual knowledge of how electronic devices work. The P-N junction diode is the building block of more advanced semiconductor devices. This exploratory study investigates the representations that students use to describe the behavior of a P-N junction diode. Participants were 3rd year students enrolled in a required introductory course in semiconductor physics. Each student participated in a one hour individual semi-structured ''think-aloud'' interview where he/she had to conceptually solve problems related to P-N junction diodes. Although these semiconductor physics courses aim to develop foundational knowledge for future device design engineers; the results of this study suggest that even successful upper division students majoring in electrical engineering may not have a good conceptual grasp of key concepts related to the diode by the end of the course. For example, many could not correctly differentiate between the linear (or resistive) behavior of an N-N junction and the non-linear behavior of a P-N junction diode. Half of the students in this study did not use their previous knowledge including current-voltage (I-V) curves to perform reality checks. The students struggled with both the macro-level behavior of a P-N junction diode and the underlying micro-level phenomena. By investigating the roots of students' challenges, this study supports the need for new teaching approaches to facilitate better conceptual understanding in introductory semiconductor physics courses.

Keywords: Diode; semiconductor physics; electrical engineering education; conceptual understanding; misconceptions

Problem-solving is a critical skill for engineers, and thus a critical skill for engineering programs to teach. Although various approaches to address problem-solving exist, none uses nonlinear, unscaffolded, unstructured, open-ended problems provided by practicing engineers. To address this shortcoming, such authentic engineering problems (AEPs) were incorporated into a heat transfer course. AEPs are authentic problems developed by practicing engineering and are representative of the unstructured, open-ended problems encountered in industry. To make space for students (N = 35) to work on AEPs in class, the course was inverted, meaning that the standard course lecture content was moved online. This AEP Centered Learning (AEPCL) format was assessed by three measures—talk-alouds, student self-evaluations, and solution evaluations. Across all assessments AEPCL led to improved problem solving. Comparisons to the same course taught in a traditional format (N = 32) showed that these improvements came with no cost to students' understanding of the content or loss of ability to solve standard textbook problems.

Keywords: authentic engineering problems; problem solving; flipped classroom; heat transfer