Volume 32 Number 1(A) 2016 ISSN 0949-149X

The International Journal of Engineering Education

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Contributions in: Taxonomy of Keywords, Student Misconceptions, Presentation Slides, Design Projects, Innovation, Critical Thinking, System Thinking Skills, Empathic Design, Assessment, Blended-Learning, E-Learning, Gender, Diversity, STEM, PBL, Laboratory Capacity, Engineering Mechanics, Thermodynamics, Mathematics, Neural Networks, Aerospace, Marine Engineering, Software Engineering, Industrial Engineering, Laboratory Capacity, Simulators

The diversity of engineering education research provides an opportunity for cross-fertilization of ideas and creativity, but it also can result in fragmentation of the field and duplication of effort. One solution is to establish a standardized taxonomy of engineering education terms to map the field and communicate and connect research initiatives. This report describes the process for developing such a taxonomy, the EER Taxonomy. Although the taxonomy focuses on engineering education research in the United States, inclusive efforts have engaged 266 individuals from 149 cities in 30 countries during one multiday workshop, seven conference sessions, and several other virtual and in-person activities. The resulting taxonomy comprises 455 terms arranged in 14 branches and six levels. This taxonomy was found to satisfy four criteria for validity and reliability: (1) keywords assigned to a set of abstracts were reproducible by multiple researchers, (2) the taxonomy comprised terms that could be selected as keywords to fully describe 243 articles in three journals, (3) the keywords for those 243 articles were evenly distributed across the branches of the taxonomy, and (4) the authors of 31 conference papers agreed with 90% of researcher-assigned keywords. This report also describes guidelines developed to help authors consistently assign keywords for their articles by encouraging them to choose terms from three categories: (1) context/focus/topic, (2) purpose/target/motivation, and (3) research approach.

Keywords: educational level; educational setting; outcomes; research approaches; theoretical frameworks

Conceptual misunderstanding, also known as misconception, is common among many learners, especially novice learners, and often results in learners' poor academic performance in many disciplines. The present study focuses on two fundamental and critical concepts in physics and engineering mechanics education: force and acceleration. The present study pieces together scattered literature information on student misconceptions about force and acceleration, and develops a comprehensive list of all possible categories (or types, or "symptoms") of student misconceptions: 38 misconceptions (in two categories with nine sub-categories) about force and 15 misconceptions (in three categories) about acceleration. The most commonly reported misconception about force is "motion implies force" for both K-12 (kindergarten to grade 12) and college students. The most commonly reported misconception about acceleration is "acceleration is always in the direction of motion." The present study further examines the reasons reported in the existing literature for why students have various misconceptions about force and acceleration. These reasons are grouped into four categories: (1) preconceived misunderstanding; (2) incomplete or partial understanding; (3) wrong interpretations and comprehensions; and (4) vernacular misunderstanding. Methods of how to correct student misconceptions are also suggested and discussed in this paper.

Keywords: student misconceptions; force; acceleration; physics; engineering mechanics

In this study, we measured chemical engineering students' response times to multiple choice thermodynamics concept questions while the students were engaged in technology-facilitated active learning in class. We examine response time differences for over 12,000 responses: between correct and incorrect answers, with and without written explanations to justify the answers, and as a function of question difficulty. For students who wrote a written explanation, we also investigated the length of explanation. We are interested in both implementation issues for the practitioner and in contributing to the extant understanding of the ways in which these type of question influence student thinking processes. Our findings show that students who answer correctly take less time to answer easy questions than those who answer incorrectly, but more time for more difficult questions. Response times are correlated with question difficulty when the correct answer is chosen, but not for incorrect answers. Moreover, for easy questions, explanations that are correct are likely to contain more words whereas for more difficult questions explanations associated with incorrect answers contain more words. When accounting for difficulty, it takes students about 100 seconds longer to provide a written explanation justifying their answer choice. However, differences in response data suggest that students who justify their answers in writing also more commonly activate thinking processes that focus on domain-specific knowledge. When possible, we advocate using written explanations in conjunction with multiple-choice concept questions during active learning in class, arguing that the short additional time needed to allow students to type explanations activates more deliberate thinking processes.

Keywords: peer instruction; misconceptions; thermodynamics; clicker questions

Many undergraduate engineering programs use presentations as a means of assessing students' learning and technical communication skills, but the task of identifying slide structures that foster the presenter's thinking about his or her topic has received little attention. In most cases, students create topic-subtopic structure slides that follow the default settings of programs such as Microsoft PowerPoint. Our study explored the premise that the structure of a slide can also influence the presenter's understanding of the content. We asked 120 undergraduate engineering students to create slides that could be used to teach other students how MRI scans work. Roughly half of the participants (n = 59) were tasked with creating assertion-evidence slides. In the other condition, 61 participants created slides using a structure of their choosing. More than 80 percent from this second group created topic-subtopic slides. Within 24 hours, we gave the participants an unannounced post-test of comprehension. Results revealed a statistically significant advantage ($p < 0.05$) for participants who created assertion-evidence slides. Two takeaways from our study are (1) that the assertion-evidence structure led to a statistically significant increase in the presenter's understanding of the content, and (2) that the instruction needed to teach the assertion-evidence approach to the student presenters was minimal.

Keywords: presentation slides; PowerPoint; assertion-evidence; communication

Many senior level capstone design courses encourage students to develop innovative solutions to open design projects from industry partners. Student teams that function at a high level are more likely to develop innovative solutions. Prior researchers have proposed that there are four stages to the development of groups: forming, storming, norming, and performing. It has been seen that students often get ''stuck'' in the storming stage and only after they coalesce as a team and set common goals (Norming Phase) can they perform at the highest level to achieve said goals (Performing Phase). The research presented in this paper, focuses on two main areas: (1) understanding what motivates undergraduate engineering students when working on design projects and (2) determining the effects of goal alignment interventions on design teams. A study of senior-level mechanical engineering students was conducted to determine if the effects of setting common goals could be quantified. Five of the total eighteen design teams were selected and guided to set common goals during their design project. Each team was composed of four or five mechanical engineering students. It was found that the teams that received ''interventions'' had an increase in level of performance (p-value = 0.14) and motivation (p-value = 0.19) when compared to teams that were left to their own devices. The main conclusions are summarized as: (1) interventions can be effectively used to explicitly set common goals for the group, (2) interventions have immediate positive effects on the levels of performance and levels of motivation, and (3) a positive correlation between performance and motivation is found.

Keywords: capstone design; goal alignment; innovation

Understanding, evaluating, and promoting individual innovativeness is a critical step in cultivating engineering leaders for the future, and yet the study of engineering innovativeness as a domain-specific construct is relatively new. We examined 20 characteristics of engineering innovativeness identified in previous research and 27 related measures from the literature through two lenses: (1) their relationship to key elements of cognitive function (i.e., cognitive level, cognitive style, and cognitive affect) and (2) the categorization of their underlying constructs as innate or learned. The aim of this mapping exercise was to determine whether the 20 characteristics could be assessed using existing instruments, or whether the development of a new instrument was required. In total, 81 constructs were evaluated from the 27 instruments. From this critical review, it is clear that a single, comprehensive, and rigorously validated instrument does not yet exist to assess the full range of knowledge, skills, and attributes that are indicative of engineering innovativeness. This work highlights the potential for such an instrument to help transform engineering education by providing students and instructors with new insights into the formation and nurturing of engineering innovativeness.

Keywords: innovation; assessment; cognitive function

Many program outcomes required by ABET 2000 criteria require that students learn critical thinking and communication skills as part of the engineering curriculum. In this study, we attempted to improve forty-nine first year undergraduate engineering students' critical thinking skills through two assignments based on the Paul-Elder model of critical thinking, which incorporates characteristics of eight elements of thought of critical thinking and has been contextualized specifically for use in engineering. Two methods were employed: problem-based learning and writing for reflectivity. Students first worked in teams to solve two engineering problems, and then each individual student wrote first and final report drafts for each of the problem solving tasks. Writing fellows provided structured feedback to students on each of their first draft reports based on one of two grading rubrics used to assess reports. Over the course of the semester, students showed improvement in overall critical thinking skills and in some, but not all, of the eight elements of critical thinking according to both grading rubrics. Based on these results, we offer suggestions for the teaching of critical thinking skills to undergraduates in engineering and a call for future empirical research.

Keywords: critical thinking in engineering; writing fellows; problem-based learning; Paul-Elder model of critical thinking; ABET 2000

A unique course named "Introduction to Engineering Design" has been recently developed and implemented at the Technion—Israel Institute of Technology. The course allows top 12th grade students who are majoring in science and engineering to experience engineering design. At the end of the course, the students plan and implement—on a team basis—a real-time control system for an electric motor. The course is intended to increase its graduates' motivation in science and engineering, develop their systems thinking skills and train them in teamwork, as such skills will assist them in their future engineering work. The study described in this paper examined—through quantitative and qualitative tools—to what degree the course's first two objectives had been attained. Thirty-two students participated in the study and its findings indicate an improvement in the students' intrinsic motivation to study science and engineering (medium effect size) and in their systems thinking skills (large effect size).

Keywords: engineering education; high-school curriculum; motivation; systems thinking

This study explores the role of empathic design techniques on solving design problems in a developing world context. In our study, over 100 graduate students were asked to individually conceptualize and design an extremely affordable washing machine to be used in developing countries. All participating students, many of whom had significant industry experience, were enrolled in a graduate-level product design course. This course is as much about design thinking and learning as it is about design innovation, creativity and doing design. The design of an artifact is addressed from a multidisciplinary perspective that includes determination through inspiration, ideation, and implementation using a design thinking framework. Student submissions were categorized based on (1) design methods such as concept generation, product definition, prototyping and design verification, and (2) student

demographic information. The application of the design methods on the project influenced the further development of class-based exercises that infuse empathy into design. The study presented here also provides a framework for engaging distance-learning students within hands-on empathic-design exercises. The results show that techniques such as interviews of focus groups and immersive practices help students to better understand user needs in developing world contexts, leading to more feasible design solutions. Visual thinking was also linked as an effective means to engage students in empathic design without the use of physical materials.

Keywords: empathic design; engineering education; distance learning

The key intended learning outcome of interdisciplinary engineering courses and programs is the development of students' ability to integrate knowledge known as integrated understanding. Still, there are only few examples of assessment tasks designed to deliberately assess this attribute in engineering education, and little is known about how to develop credible scoring rubrics that can assess integrated understanding promoted by specific interdisciplinary courses. In this paper we offer an operational definition of integrated understanding developed based on the literature. We also present a method for designing credible scoring rubrics for course-specific integrated understanding based on this definition. Our process establishes the rubric's validity through aligning course learning objectives with the rubric criteria and reliability through involving course teachers who often come from different disciplinary backgrounds in developing performance-level descriptions. We tested the method by applying it to design a rubric for evaluating integrated understanding in an interdisciplinary undergraduate elective course in Biologically-Inspired Design. The resulted rubric was used to grade students' reports (n = 27) by the course teachers who came from disciplines as varied as Biology and Engineering. Reliability calculated through Intra-Class Correlation (ICC) was good to excellent with regard to all criteria. The rubric can thus be reliably used by the course teachers to draw valid conclusions regarding progression in students' integrative understanding in their course. Additionally, this method can be used to establish credible scoring rubrics for evaluating students' integrated understanding following participation in other interdisciplinary engineering courses.

Keywords: assessment; integrated understanding; biologically-inspired design

After their first year roughly 50% of engineering students do not continue in that major. One cause could be that students have little idea as to what the profession of engineering is about. Freshman introductory courses provide a first approach to the engineering profession. Therefore, understanding the role of introductory engineering courses to increasing student knowledge of the profession is a relevant issue. The purpose of the study is to describe how student perceptions of the engineering profession overall change as a result of their educational experience in an introductory biomedical engineering course. This is a pre- post-test with no control group study design. One class (n = 41) on a first-year biomedical engineering course participated in a hybrid Project-based-learning (PBL)-lecture learning strategy. A survey composed of a demographic and 5-point Likert (''1'' is strongly disagree and ''5'' is strongly agree) sections measured students' perceptions of the engineering profession and was administered (paper-based) to all the students enrolled on this course. The students' perceptions of the engineering profession were pooled into 3 main groups of skills, i.e. Technical skills, Professional skills, and Project management skills. Wilcoxon signed-rank test statistics were conducted to analyze the research question. Our analysis showed statistically significant results (pre-survey mean and SD: 4.01, 0.07; and post-survey mean and SD: 4.21, 0.05, $p < 0.003$), indicating the students' overall perceptions of the engineering profession had significantly improved by the end of the course. The results indicated that the students' overall perceptions of the engineering profession had significantly improved by the end of the introductory course.

Keywords: classroom assessment; engineering pedagogy; project-based-learning; student retention

Solving problems is one of the key tasks of the mathematics learning process. It requires teachers to prepare problems, correct them and return feedback to the students. The capability to automate all these steps would be a powerful tool for teachers, especially in courses with a lot of students. In this paper, we propose a method to automatically create and correct mathematical problems. The proposed approach codifies different type of problems in a single template that maintains the descriptor of the problem, a set of parameters, and a correction code. Once the template has been created, our method automatically generates different problems that can be automatically corrected using the correction code. The method has been implemented and integrated in an e-learning platform that provides all the functionalities of learning management systems. The purpose of this paper is twofold, first, present the method defined to automatically create and correct mathematical problems and how it has been integrated in our e-learning platform, and, second, evaluate its use in different courses of our University. To reach the second objective, we will describe how this approach has been used in the Calculus and Algebra courses of the engineering degree of our university. We will also show the results obtained in the last five courses, from 2010 to 2014, considering more than 500 students. From the ANOVA test, considering course by course and also the five courses together, we confirm that the mean scores of students increases when the number of solved exercises increases. From the questionnaires that users filled at the end of the course to evaluate their experience and the benefits of the proposed approach, we will see that students feel more motivated to work. In addition, the automation of many teacher tasks allows them to better distribute time and carry out a better student follow-up.

Keywords: blended-learning; automatic problem creation; automatic correction

Previous research suggests strong connections between students' mathematics background and their persistence in engineering career aspirations. This study expands on that research by examining how mathematics identity impacts the choice of engineering careers for male and female students. Data used in this study were drawn from the Factors Influencing College Success in Mathematics project, a nationally-representative survey garnering responses from 10,437 college calculus students. Results from an exploratory factor analysis validated the mathematics identity framework proposed. Additionally, results from a logistic regression indicate that mathematics interest and recognition in mathematics significantly predict the choice of an engineering career, even after controlling for SAT/ACT mathematics scores and demographic background, such as parental education. Moreover, the interaction between recognition in mathematics and gender is also significant and indicates that being recognized in mathematics has a stronger positive impact on the choice of an engineering career for females than for males.

Keywords: mathematics identity; engineering; higher education; gender

This work characterizes and optimizes an outlier detection algorithm to identify potentially invalid scores produced by jury members while grading engineering design projects. The paper describes the original algorithm and the associated adjudication process in detail. The impact of the various conditions in the algorithm on the false positive and false negative rates is explored. A response surface design is performed to optimize the algorithm using a data set from Fall 2010. Finally, the results are tested against a data set from Fall 2011. It is shown that all elements of the original algorithm (the base rule and the three additional conditions) play a role in the algorithm's performance and should be included in the algorithm. Because there is significant interaction between the base rule and the additional conditions, many acceptable combinations that balance the FPR and FNR can be found, but no true optimum seems to exist. The performance of the best optimizations and the original algorithm are similar. Therefore, it should be possible to choose new coefficient values for jury populations in other cultures and contexts logically and empirically without a full optimization as long as the algorithm assumptions are valid and the limitations for its use are well understood.

Keywords: evaluation; outlier detection; optimization; engineering design; design jury

The objective of this study is to introduce an intelligent E-Learning software system, which aims to improve students' motivations and academic achievements in computer programming courses. The system is based on an intelligent analysis approach, which is formed via an Artificial Neural Network model trained by Cognitive Development Optimization Algorithm. This intelligent approach tries to provide appropriate materials to students by evaluating learning levels. At this point, types of learning levels are defined by teachers and associated with specific abilities regarding to computer programming. After determining learning levels according to results of the performed activities, it is then possible for software system to provide appropriate materials/applications corresponding types of low learning levels. Thanks to the system, it is possible to learn abstract, difficult computer programming based subjects easily. In order to have idea about effectiveness of the system, it was evaluated in some computer programming courses with contribution of 110 students and eventually, positive results were obtained after several evaluation works.

Keywords: e-learning; artificial neural networks; cognitive development optimization algorithm; computer programming; artificial intelligence; intelligent software system

This study evaluates whether online peer assessment increases student participation and thus improves their learning achievement in a database system design and analysis course. To understand the effectiveness of online peer assessment within a Web 2.0 environment, we implemented an e-learning 2.0 platform to achieve the research purpose. Data were collected from student participants in a database system design and analysis course, including Really Simple Syndication (RSS), blogs, Wiki, and other online forums. We used a quasi-experimental design method to divide participants into an experimental group (N = 52) and a control group (N = 60). The control group was taught using a traditional face-to-face teaching method, while the experimental group followed the same course outline but was additionally assisted by the e-learning 2.0 platform, which incorporated peer assessment mechanism. The results indicated that students in the experimental group had significantly better academic results than those in the control group.

Keywords: e-learning 2.0; interactive learning environments; evaluation of e-learning systems; peer-assessment

Traditionally, students from higher training cycle and upper secondary school education access higher technical education with a wide range of access marks in each group. The purpose of this article is to analyse how students' backgrounds and access marks really influence their success in the first academic year and further evolution to obtain the degree of Technical Architecture.

To achieve this aim, the progress of students from different backgrounds was analysed for three academic years from 2002/2003 to 2004/2005 prior to the implementation of a curriculum adapted to the European Higher Education Area (EHEA), so that the curriculum change does not introduce noise in the data. That involves 983 students in this study. Moreover, most students in the new curriculum have not completed all the courses.

It was found that, once students had completed the first semester, a selection stage in the studies that were analysed, their background did not influence their performance. However, it was also found that the access mark influenced both the mark for the selection stage and academic performance until completion of the degree.

Keywords: higher education; academic performance; learning outcomes; background influence

K-12 engineering is a critical platform for achieving integrated science, technology, engineering, and math STEM teaching and learning in the Unites States. This has fueled research in the development and testing of integrated STEM curricula. This study examines the contrasting ways in which a prescribed curriculum is translated into practice. The study examines the implementation of 12-week secondary engineering unit (helmet design) by a teacher with high content knowledge in engineering in a rural/suburban school with 20 students. The unit was designed with significant input from a university-based team including content experts, learning scientists, master teachers, classroom teachers, and school district administrators as part of a grant focused on the creation of a high school engineering course. Five strands were identified in the unit for analysis: assessment, activities, apparatus, technology, and standards. Findings indicate much alignment with apparatus, standards, and technology strands and disparity within the assessment and activities strands between the prescribed unit and its enactment in the course by the teacher.

Keywords: STEM integration; K-12 engineering education; engineering curriculum

The demand for diversity in the population of engineering professionals is growing, following both the general demand for engineering professionals and the explicit need for more diverse teams. Thus, the engineering education community is becoming more interested in identifying factors that influence students' satisfaction with their engineering education. The purpose of this study was to elicit students' perception of an industrial engineering program in Germany and identify differences in students' perceptions based on their migration background, being a first-generation student, and their gender. We solicited survey data from 132 undergraduates of an industrial engineering program of a large University of Applied Sciences in Southern Germany. We tested whether there were significant differences regarding the satisfaction with the study program (e.g. perceived time and performance pressure, role models), intra-personal variables (e.g. locus of control), preferences regarding gender distribution, and perceived discrimination. Results indicate differences in the perception of and approach to the industrial engineering program between majority and non-majority students. Satisfaction with the program and perception of the faculty as role models were

somewhat lower for students with a migration background and female students. First-generation students differed in their perceived locus of control; students with a migration background showed more extrinsic motivation and perceived more discrimination. Implications focus on combining psychological and structural interventions that address and recognize diverse perceptions and approaches in students and academic affairs practice.

Keywords: engineering education, diversity, gender, migration background, first-generation college students

The objective of this work is to present an approach to increase the number of students who could be accommodated in a laboratory for gear measuring course without the need to increase the number of physical equipment. The approach is based on a remote control freeware application, and special design of the locations of the audiovisual media. Students participated in a real time measuring process from their own computers under the supervision of the instructor. The methodology was assessed by means of a class experience in a measurement laboratory, where a group of students attended the explanations of two lecturers. During the session, the participants were able to control a coordinate measuring machine from their laptops. Finally, students' satisfaction was assessed with a questionnaire based on five-level Likert items, obtaining positive results.

Keywords: interactive learning; metrology; remote control; educational-resources optimization; gear measurement; active methodologies

A design and build project for undergraduate students has been established by the US Air Force Research Laboratory as part of an aerospace outreach program. In the 2011–2012 academic year, undergraduate students from six universities participated in designing and testing a thrust vectoring system for a small (20 pound-thrust) turbojet engine. A description of the student designs and the project parameters is provided in this article. Student and professor exit surveys were taken with almost all participants contributing to these surveys. Based on the survey results and the professors' insights, learning outcomes and student impact were assessed. In addition, lessons learned during the project-based learning activity are described in this paper. The project proved to be extremely successful, and professors and students in engineering can learn from the different approaches taken by the six different teams and the project itself. Industry will be interested in the depth and breadth of the undergraduate project that is implemented to educate the future engineering workforce.

Keywords: project-based learning; engineering education; aerospace; propulsion outreach program

This paper presents the results of investigating two teaching approaches to students studying a course on Numerical Simulation in Aerospace Engineering. In one approach a group of students used Simulink only and in the second another group used Simulink and a physical flight simulator. The impact on students' motivation and academic achievement was assessed by the use of hierarchical clustering and linear discriminant analysis. There were 42 undergraduate students split into two groups. The conclusion is that by using a flight simulator students enjoy to a larger extent the learning process and thus are more motivated and eventually obtain better marks.

Keywords: flight simulator; rubric; education; Simulink; linear discriminant analysis

A software engineering capstone course is often used for the introduction of agile methods like Scrum. Apart from exposing students to state-of-the-art topics, the capstone course also enables teachers to use modern ways of teaching through practical problem solving and gives researchers opportunities to conduct empirical studies with students as subjects. In order to satisfy the needs of all parties involved, a good computerized support tool is needed. The students need such a tool to manage their projects, the teachers require instruments for maintaining project requirements and monitoring student progress, while the researchers are interested in data for evidence-driven assessment of the development process. In this paper, an example of such a tool that was developed to support a Scrum-based software engineering capstone course is described. The course design, which requires students to develop a quasi-real project, is described first. Following this, a step-by-step description of the course execution is provided and the tool support of each step is illustrated. Finally, the opinions of 57 students obtained through an anonymous survey after using the tool for the first time are analyzed. The students found the tool intuitive and easy to use, providing good visualization of the project progress and making the execution of their projects simpler and more efficient. The tool gives directions on how their collaboration should proceed and prevents them from exploring their projects blindly. By visualizing the development process, it helps all parties involved to know what each team member is doing, thus preventing procrastination and "free-rider" syndrome.

Keywords: software engineering education; agile methods; Scrum; capstone course; project management; effort estimation

This article introduces a new fully operative teaching simulator for all kind of marine power stations, both placed on board or on land, allowing to establish an innovative procedure to develop standalone low cost simulators for high level professional instruction of marine engineers, that can be run on conventional computers. This kind of low cost simulators opens a new way not only in the teaching and training of marine engineers, but also in the design and implementation of new power facilities, allowing to train the operators prior to their work in the real installation.

Keywords: teaching simulators; International Maritime Organization (IMO) standards; EES