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Contributions in: Motivation, Students' Perceptions, Teamwork, Board Games, Decision Making, Gender Diversity, Intellectual Property, Capstone Projects, Enhancement of Learning, Inquiry-Based Learning, Product Design, Design Innovation, Airfoil Design, Software Engineering, Open Source Tools, Control Systems, Predictive Control, Chemical Engineering, Physics and Mathematics

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Brett D. Jones, Jason W. Osborne, Marie C. Paretti and Holly M. Matusovich	1340–1356	Relationships among Students' Perceptions of a First-Year Engineering Design Course and their Engineering Identification, Motivational Beliefs, Course Effort, and Academic Outcomes

The MUSIC Model of Academic Motivation and a model of domain identification have been shown to be useful models to explain students' motivation. We used these models to examine the extent to which students' perceptions of a first-year engineering cornerstone course affected their engineering identification and motivational beliefs (i.e., engineering utility, engineering program belonging, and engineering program expectancy), as well as the extent to which students' engineering identification and motivational beliefs affected their course effort, course grades, and engineering major and career goals. We surveyed 365 first-year engineering students enrolled in an introductory design course at a large U.S. public university. A series of structural equation models were estimated, with each model answering a different question and examining a different outcome. The results provide evidence to support the validity of the MUSIC model and model of domain identification with a sample of undergraduate engineering students. This evidence includes the fact that significant relationships existed between variables that the model predicted should be related, such as course perceptions, domain identification, motivational beliefs, effort, and academic outcomes. Because students' perceptions of the MUSIC model components in the engineering course were related to students' engineering identification and motivational beliefs, it might be possible to develop course curricula and methods directed towards the MUSIC components that could foster these important academic outcomes.

Keywords: motivation; domain identification; MUSIC Model of Academic Motivation; effort; career intentions; retention

Antonio Maffei, Hakan Akillioglu and Niels Lohse	1357–1366	Analysis of the Student Perception of the Link between Product and Production System: Towards Effective Strategies to Teach the Holistic Nature of Product Design
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Product design has a huge and widespread impact on the eventual design of the related production processes, such as procurement, manufacturing, assembly, maintenance and recycling, amongst others. Understanding the full the nature of such a complex relationship is a cornerstone in the professional development of any production engineering student and practitioner. Acquiring sophisticated concepts is a long process consisting of acquiring the necessary notions and mentally structuring them through different semantic links in a consistent body of knowledge. This generates a large set of intermediate states between the novice and the expert. Phenomenography focuses on identifying and classifying these perceptions with the aim of identifying the related pattern for good learning. In particular, this phenomenographic analysis focuses on investigating the students' perception of the articulated link between the design of a product and that of the related assembly process. The study is based on courses that exploit the principles of Design for Assembly (DFA) methods to present and detail such a domain. In the first section of the paper, the aforementioned focal issue is fully characterized as a 'Threshold Concept'. The central part of the paper describes five generic levels of understanding of such a matter: from a simple mechanical use of DFA to a more sophisticated correct holistic understanding of all the implications of such a tool. The classification has been inferred through a series of informal, semi-structured interviews with the students. The characterization introduced is finally discussed with the aim of disclosing the pattern of good learning that, in turn, could provide the base for studies aimed at disclosing useful hints for the effective development of the related teaching activities.

Keywords: product design; production system design; phenomenography; Design for Assembly

Hoda Baytiyeh and Mohamad K. Naja	1367–1375	Motivation to Volunteer in Earthquake Mitigation Programme among Engineering Students
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Lebanon has historically suffered from the effects of devastating earthquakes. To successfully mitigate the cataclysmic effects of such looming disasters, effective preparatory activities and response strategies relying on government resources, community engagement and volunteering programs are crucially essential. The objective of this study is to assess the willingness of engineering students to join earthquake risk reduction programs initiated and led by universities and to determine their motives behind such engagements. In addition, the study aims to identify the competencies of engineering students in supporting response operations when a future earthquake strikes. Lebanese senior and graduate engineering students ($n = 332$) were surveyed. The findings revealed a strong tendency for Lebanese engineering students to participate in such volunteering programs, and that learning and altruistic factors are the leading predictors behind the intended participation. However, engineering students showed poor competencies and skills that are essentially needed for such a mission. This study emphasises the role of universities and engineering educational and professional programs in earthquake risk mitigation and response operations in future earthquake disasters.

Keywords: volunteering programs; engineering students; motivation; earthquake risk reduction

The importance of developing teamwork skills among engineering students is crucial, but many intervention strategies are cumbersome, time-consuming, or inappropriate for engineers. This report provides details on an intervention strategy designed to improve teamwork skills among engineering students within the timeframe of three hours, with minimal preparation from the educator's point of view. The activity centers on a commercial cooperative board game, *Pandemic*. In cooperative games, the students play against the game cooperatively rather than against each other competitively. As a low-risk, self-contained activity, students self-identify the importance of good teamwork skills and the detriment of poor teamwork skills. The participants of this study scored significantly higher than more senior students on a teamwork assessment instrument. In addition, they scored significantly higher in the categories of communication, task planning/execution, and goal setting: all necessary skills in the game. This report also highlights the importance of aligning educational goals with features of the game to achieve its success.

Keywords: teamwork; freshmen; games; alignment

In the United States of America, the federally funded National Science Foundation (NSF) makes significant investments in exposing undergraduate students to academic research in engineering and science through its Research Experience for Undergraduates (REU) program. REU grants provide individual faculty members (and teams of faculty) across the USA with funds to conduct program sites, which generally occur during the summer months and are thematically organized around a specific area of research. These faculty administrators are not only responsible for providing a high quality research experience to participants, but are also focused on successfully recruiting a diverse pool of applicants and ensuring acceptances from highly competitive participants. This study examines how applicants view the importance of programmatic and application factors. With a goal to provide practical implications for program administrators and others interested in promoting undergraduate research participation, this study primarily considered items identified as controllable by the site directors/administrators to improve recruitment efforts. This study also considered some additional factors, such as the geography of programs to which applications are submitted, that could potentially give insight into how students are choosing programs. An online survey was created and distributed to current program participants by participating research site administrators at 34 American institutions yielding 129 complete responses. Initial results confirmed that most applicants seek positions within an array of sites encompassing a broad area (median values: three applications and 763 miles from home). Analysis of participants' responses showed that 34% were offered multiple positions and 17% of respondents declined another employment offer before accepting their current position. The primary factors that student applicants consider important for impacting their selections were (1) focus of the research project, (2) stipend or compensation, and (3) the date they receive their acceptance and offer. The first factor aligns with previous findings, but the second and third factors demonstrate how the program administrator can influence the selection, which has not been previously observed.

Keywords: research experiences for undergraduates; undergraduate research; student decision-making; summer programs

Design teams are commonly formed in engineering courses with the expectation that gender diversity will lead to more innovative solutions, but few studies have examined this relationship. In this study, we investigated whether the variety of ideas and the innovative qualities of team design solutions are related to team gender diversity. The research participants were 148 engineering students working in 37 teams. These teams were identified as gender balanced or all-male based on their gender composition. Their idea generation outcomes and final design solutions were evaluated using an established variety metric and a new innovation potential metric developed by the authors. The innovative potential, variety scores, and correlation between variety and innovation potential were compared with respect to team gender diversity. The results indicated that gender balanced teams were no more innovative than all-male teams, nor were there any significant differences in the variety of alternative solutions between the two groups. Gender balanced teams, however, did demonstrate a strong positive correlation between variety and innovation potential. Results suggest that diversity, defined by gender alone, may not increase the innovation potential of student design teams but may support innovation in the presence of other factors. Efforts should focus on helping teams better utilize their diversity to improve their ability to be innovative.

Keywords: design; gender diversity; idea variety; innovation potential

The use of active learning methodologies is an issue of great concern for improving education quality. In this paper, the authors provide an innovative point of view for an Intellectual Property (IP) course. This course is designed by engineers for engineers. The course has been designed so that the students have to complete three different projects. The first project is centred on trademarks, the second one on patents and the third one is the extension of one patent to others countries, that is, the national stage of the patent. According to the results of the evaluation of the projects, most of the learning objectives have been achieved and the students have improved their skills, such as self-learning, creative thinking and troubleshooting. This paper describes the implementation of these different projects. These experiences can be easily replicated in other universities.

Keywords: active learning methodologies; engineering education; intellectual property

In student feedback, many students expressed difficulty with the concepts being taught. There was a difficulty with quick, in-class retrieval of information. To facilitate transfer, understanding and retention of knowledge there needs to be prior knowledge in the long-term memory. In the case of complex engineering problems, the performance outputs are a function of many input variables. Airfoil design is a good example—the engineer needs to understand the dependence of performance parameters on the input conditions along with the physical phenomena. Visual representation is a powerful means of depicting cause and effect relationships. It can be reasoned by adding relational, interpretive visuals to a lesson, a higher level of learning will occur. In the proposed interactive program the student is given control of input variables and can see the influence these have on the primary aerodynamic concepts. It creates realistic configurations from complex theoretical calculations, facilitating the storage of information in the long-term memory. This when complemented with traditional teaching methods, allows the student to develop conceptual understanding. The programme was used in second year undergraduate engineering teaching and over a three-year period was monitored and improved. Students' performance was used to assess the effectiveness of the learning technique, as was student module feedback. The average class size for courses investigated was 26 students. The students performed better using this approach. It generated a motivation for further enquiry in the students and created an enthusiasm for student-student and student-lecturer interaction. This agrees with the constructivist theories and how social psychology affects learning.

Keywords: technology education; constructivist learning; GUI; airfoil design

Inquiry-based learning (IBL) is an inductive pedagogy that best enables learners to construct knowledge, to develop high level reasoning skills, and to increase interest and learning motivation with the use of the contemporary technology-based learning environments. In IBL, students' self-directed learning is centred on multi-parametric problems that do not have a single correct answer, but they need to find the most desirable behaviour/attitude. Therefore, clear evidence of IBL heterogeneous learning achievements measurement, based on reliable and valid instrument, is still lacking. This paper describes the design and experience of the new student-centred IBL model of open learning at the technology education course, which enables a high level of active self-directed learning. In a treatment group were ninety-one students who experienced IBL in a three-day course activity, while in the control group were three hundred and thirty students. Identical forms of technological literacy tests were carried out as pre- and post-tests. Quantitative research methodology was used to analyse the collected data. The multifaceted nature of IBL and its impact were successfully measured with a technological literacy test. The findings of this study showed that IBL is an effective teaching approach in technology education. The effect size was judged to be large and positive in technological knowledge acquisition, in problem-solving skills development, and in critical thinking and decision-making abilities development. A proposed model suits both females and male students equally. Therefore, a high possibility exists for the use of the new IBL model for technology education.

Keywords: inquiry-based learning; water turbine optimisation model; technological knowledge; problem-solving and research skills; critical thinking and decision-making ability; self-directed learning

Mert Atilhan, Fadwa Eljack, Hassan Alfadala, Jeffrey E. Froyd, Mahmoud El-Halwagi and Vladimir Mahalec 1450–1460 Inquiry Guided Learning in a Chemical Engineering Core Curriculum: General Instructional Approach and Specific Application to the Fluid Mechanics Case

This paper presents results from a preliminary study of the effectiveness of using inquiry-guided learning instructional strategies both in chemical engineering classrooms and laboratories. For readers unfamiliar with the instructional strategy, the paper describes the general approach and then reports on results of its application for the fluid mechanics course taken by undergraduate students in the Chemical Engineering Department at Qatar University. Inquiry-guided activities were developed after a series of interviews with recent chemical engineering graduates and employers to gather data on difficulties of chemical engineering graduates during the transition period from the university to industry. Some common daily problems were gathered, discussed, listed and used to formulate in an inquiry guided activity structure. Students were asked to participate in a role-play approach in which client-contractor relationship and rules of engagements were simulated. Both laboratory projects and in-class inquiry guided approach were conducted. Student performance and ability to approach conceptual problems and design-related issues were monitored and graded. Assessments were done after initial coverage of fundamentals of fluid mechanics (8 weeks into the course). Activities promoted in-class engagement and student performance was observed to enhance student performance and engagement to subject when compared to years at which the inquiry teaching methods were not used. This observation is observed to be valid for both with respect to conceptual approaches as well as design-related issues in the early stages of chemical engineering education.

Keywords: inquiry guided learning; teaching chemical engineering education; chemical engineering core curriculum; fluid mechanics

Jari Vanhanen and Timo O. A. Lehtinen 1461–1475 Software Engineering Problems Encountered by Capstone Project Teams

Capstone projects are a common part of engineering education. In a capstone project, learning takes place mainly through solving problems during the project. Therefore, understanding what problems the capstone project teams encounter increases understanding on what the students can learn. We collected problems encountered by eleven capstone project teams in a software development project course at Aalto University. Each team used a root cause analysis method twice during their project to identify the problems and their cause-and-effect relationships. The number of identified problems was 103–247 per team. We analysed the problems qualitatively and summarized them under the following four main topics: system functionality, system quality, communication and taking responsibility. The problems created opportunities for learning about software engineering. However, in some teams the problems worsened so much that they created educationally detrimental situations. For example, learning a new programming language from scratch is valuable for a student, but it may start taking too much attention from many other educational aspects of the project. We give suggestions for mitigating the educationally detrimental situations in capstone projects. The suggestions include an iterative development process, team formation practicalities, reasonable project topics, customer education, instructions on selecting and adopting crucial tools, emphasizing learning, and adding control to ensure the use of the desired working practices. Our results help the teachers of similar courses in evaluating the potential that their courses have on reaching specific educational goals and in improving their courses by decreasing educationally detrimental situations.

Keywords: capstone project; education; problems; root cause analysis; software engineering

Deepti Mishra, Tuna Hacaloglu and Alok Mishra 1476–1485 Teaching Software Verification and Validation Course: A Case Study

Software verification and validation (V & V) is one of the significant areas of software engineering for developing high quality software. It is also becoming part of the curriculum of a universities' software and computer engineering departments. This paper reports the experience of teaching undergraduate software engineering students and discusses the main problems encountered during the course, along with suggestions to overcome these problems. This study covers all the different topics generally covered in the software verification and validation course, including static verification and validation. It is found that prior knowledge about software quality concepts and good programming skills can help students to achieve success in this course. Further, team work can be chosen as a strategy, since it facilitates students' understanding and motivates them to study. It is observed that students were more successful in white box testing than in black box testing.

Keywords: software engineering; education; testing; open source tool

Massimo Canale, Valentino Razza and Diego Regruto 1486–1498 Model Predictive Control Education using a Rapid Prototyping Industrial Platform

The recent advances in implementation methods and in the efficiency of computing devices increased the interest of industry in using model predictive control (MPC) methodologies in control applications characterized by fast dynamics. In order to cope with such a growth of interest, control designers who are adequately trained for the MPC design practice are needed. In this regard, suitable experimental activities must be set up inside the educational programmes involving MPC subjects. In this paper, rapid prototyping (RP) environments play a role of primary relevance in testing and performing MPC design iterations on a real-time system. This view introduces a flexible RP tool for MPCs developed on a National Instruments industrial device. It is aimed at allowing students with basic knowledge of predictive control theory, to train their ability in the design of MPC controllers by means of a 'learn-by-doing' approach. Experimental practice on a magnetic levitation system as well as a student assessment and survey data are presented to show the effectiveness of the proposed MPC RP environment.

Keywords: control education; model predictive control; rapid prototyping

Recent progress in the development of microactuators and other micro-devices for biotechnology has increased the demand for skilled engineers that specialize in this field. This cannot be ignored in the curricula developed by the universities for control engineering students. The presented paper describes a teaching methodology for graduate students from the control engineering department who specialize in control of biotechnological systems. A particular emphasis is put on laboratory work, where students have an opportunity to gain a practical experience in modeling and control of piezoelectric microactuators. In contrast to the existing teaching approaches, the position measurement of the microactuator stage is realized in two ways. As a result, it is possible to compare the effectiveness of positioning controllers with different position sensors. Moreover, in order to develop higher cognitive skills in students, the implemented controllers are designed from scratch without using additional packages for control system design. However, due to the limited time available for the realization of the laboratory course the students are divided into two groups. Each group (for the chosen measurement technique) designs and implements four structures of the positioning control system: the open-loop and closed-loop systems with and without a model-based compensator. The closed-loop system is based on the classical proportional-integral (PI) controller. In turn, the model-based compensator uses the inverted Preisach model (both microactuators exhibit hysteresis behavior). At the end of the course, students prepare the final joint report which includes a comparison between all implemented structures using different measurement techniques.

Keywords: piezoelectric microactuator; micropositioning; hysteresis modeling; control engineering education

**Alicia Perdígones, Eutiquio Gallego,
Nieves García, Pilar Fernández,
Enrique Pérez-Martín and
Jesús del Cerro**

1509–1521 Physics and Mathematics in the Engineering Curriculum: Correlation with Applied Subjects

This paper presents a study in which the relationship between basic subjects (Mathematics and Physics) and applied engineering subjects (related to Machinery, Electrical Engineering, Topography and Buildings) in higher engineering education curricula is evaluated. The analysis has been conducted using the academic records of 206 students for five years. Furthermore, 34 surveys and personal interviews were conducted to analyze the connections between the contents taught in each subject and to identify student perceptions of the correlation with other subjects or disciplines. At the same time, the content of the different subjects have been analyzed to verify the relationship among the disciplines. A proper coordination among subjects will allow students to relate and interconnect topics of different subjects, even with the ones learnt in previous courses, while also helping to reduce dropout rates and student failures in successfully accomplishing the different courses.

Keywords: curriculum design; higher education; Bologna Declaration; engineering degrees