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Ahmad Ibrahim
- The Challenge of Developing and Assessing Transversal Competences in Higher Education Engineering Courses** 2–13
Lucía Seguí and Miguel Galiana
- Current higher education is based on a competence development approach including generic competences for the integral development of students. Degrees have been designed based on this paradigm centered on lifelong learning, self-regulated learning strategies and active methodologies in which the student is the core of the formative process, aiming at contributing to develop the key competence learning to learn. In the present paper, strategies for generic competences development and evaluation are discussed in the context of engineering and technical courses and degrees. Challenges in competence assessment as well as alignment of formative assessment, methodologies and learning outcomes are discussed based on a series of experiences. Experience evidence that competence development requires designing activities oriented towards competence development, in which learning outcomes and assessment procedures are clearly defined. The alignment of these three elements is the key for competence development since succeeding in a course by achieving the defined learning outcomes implies succeeding in the acquisition of the generic competences planned. Through the paper it is also discussed that competence evaluation is a challenge for university teachers, for which they will need to be formed and trained, and provided with institutional support.
- Keywords:* generic competences; transversal competencies; active methodologies; competence evaluation; engineering; technical courses
- Current Trends in Attrition Considerations of Graduate Engineering Students in the United States** 14–29
Matthew Bahnson and Catherine G. P. Berdanier
- Available attrition statistics for graduate engineering students do not adequately inform current attrition research because they focus on degree completion rather than attrition or early departure; aggregate science, technology, engineering, and mathematics (STEM) students; and reflect out-of-date data. While recently some work has begun to explore doctoral attrition qualitatively, the purpose of this study is to describe current trends in graduate engineering students' consideration of departure from their programs of study by capturing current numerical data specific to engineering about students' recent attrition considerations. This is important because, since the last studies were conducted, higher education systems have experienced a global pandemic, economic downturn, and sociopolitical turmoil in the United States. Graduate students ($n = 2204$) in the U.S. completed a survey. The sample includes master's ($n = 535$) and doctorate ($n = 1646$) degree-seeking students from 27 engineering disciplines and includes U.S. domestic and international populations. A majority of students considered leaving their degree program in the month before they took the survey: nearly 70% of Ph.D. and 39% of master's students, while 31% of Ph.D. and 16% of master's students seriously considered leaving their program without their degree. Descriptive statistics provide early departure considerations by engineering discipline, gender identity, race/ethnicity, nationality, and year in program by degree sought. Comparisons between groups are presented for gender, nationality, and career stage. It is essential to have an updated and discipline-specific benchmark of attrition considerations for continued engineering education research purposes, for mentorship, and for administrative purposes. Early departure from graduate school remains a threat to innovation and broadening participation in engineering and the professoriate.
- Keywords:* graduate student; attrition; PhD; Master's; demographics
- Impact of COVID-19 on Engineering Students in the Middle Phases of the Pandemic: Academic Motivation, Valued College Experiences, and Stress** 30–47
Renee M. Clark, Mary Besterfield-Sacre, Samuel Dickerson and David Gau
- When COVID-19 struck, engineering schools responded to unique issues, including interrupted capstone projects, cooperative education, and study abroad. Students became a focus. This led to a funded study to investigate the pandemic's impact on engineering students' academic motivation, educational valuation, learning, and perceived stress, which were connected through a conceptual model. Approximately seven months after the onset, a large sample of undergraduate engineering students at a public U.S. university ($n = 1,140$) responded to a survey (41.6% response), followed by focus groups. Jones' MUSIC Model of Academic Motivation and the Perceived Stress Scale (PSS-10) were key components of the conceptual model. Seventy-eight percent (78%) said their motivation was less versus before remote instruction. Two dimensions of the MUSIC Model were only at the middle point of the measurement scale – *interest* and *empowerment*. Students scored higher on the PSS-10 ($M = 22.2$) seven months into the pandemic compared to other groups beforehand. Medium negative correlations were found between the MUSIC dimensions and the PSS-10 score, suggesting decreased motivation accompanied by increased stress. *Remote coursework* was the most-frequent de-motivator, and the valued college experience cited most was *Campus-based instruction*. The most-frequent stressor was *Academic*. In all focus groups, low or decreased motivation was mentioned. This research informs Higher Education about undergraduates' motivation and stress, in particular during COVID-19 and contributes to use of the MUSIC Model and PSS-10 with engineering students. Awareness of motivation and stress experienced during COVID is crucial for responding to future crises.
- Keywords:* COVID-19; pandemic; engineering education; stress; motivation; valuation

Aziz Shekh-Abed and Nael Barakat

Engineering, and especially hardware and software engineers, need systems thinking and abstract thinking mindset. Hands-on interactive assignments utilizing a combination of hardware and software have been shown to be the most effective methods of teaching systems thinking and abstract thinking. Nevertheless, this environment was shattered by the arrival of the COVID-19 pandemic, creating a number of challenging situations. During the pandemic, remote learning and social distancing posed the biggest challenges. Educators faced a challenge when creating hands-on and laboratory-based classes, and were forced to use innovative methods like virtual laboratories online. The research described in this paper examined the effect of changes to the educational environment caused by the COVID-19 pandemic on students' cognitive abilities development related to systems thinking and abstract thinking education. The study, which used quantitative and qualitative tools, involved 70 senior high school electronics students. According to the findings, there was a significant drop in both skills among remote group students in comparison with face-to-face group students. This study found that students are incapable of adapting to change in instruction modes if not given sufficient time, support, and communication.

Keywords: systems thinking; abstract thinking; engineering projects; electronics students; distance learning

First-Year Engineering Students' Ideation in Data Analytics

55–73

Ruben D. Lopez-Parra, Aristides P. Carrillo-Fernandez, Amanda C. Emberley, Tamara J. Moore and Sean P. Brophy

Big data analytics has grown as a valuable tool for professionals from different fields to get insights from large volumes of data and make data-driven decisions. Given this, engineering students need access to learning environments that support learning data analytics. These activities should teach students the skills to assess data, design high-quality questions, perform data analysis, and provide recommendations in a manner that is aligned with client needs. To this end, we developed and implemented the data analytics activity called "The Bike-share problem" for a First-Year Engineering (FYE) design and modeling course. To analyze the students' ideation of questions and recommendations when working on the activity, our summarized research question is: *What are the characteristics of FYE students' proposed questions and recommendations for a client as part of their data analytics project?* We analyzed questions and recommendations from teams' final reports using qualitative content analysis. Our findings show that the students' questions ranged from superficial treatments of the data that required simple analyses to deep explorations of the problem that required more complex analyses. For the recommendations, we found that model responses include considerable detail, support with data, and justification based on the client needs. While both the questions and the recommendations were important separately, we also found differences among teams' ability to align their recommendations to the client with the actual questions they were trying to answer. The differences in student responses to the activity can have many explanations as to the cause; however, we have evidence that perhaps scaffolding in the way the activity is posed and team dynamics may have affected how students responded to the activity. Finally, we provide some effective practices that interested readers may implement to design analytics activities that promote students' ideation.

Keywords: first-year curriculum; professional skills; data literacy; creativity; ideation

Multistage Sustainability Education for University Engineering Students: A Case Study from Mechanical Engineering in Technological University Dublin

74–86

Kevin Dominic Delaney

Sustainability will be a key challenge that future engineering graduates must consider when solving problems. This paper sets out the approach taken in the mechanical engineering discipline of Technological University Dublin (TU Dublin) to help students acquire and develop the requisite skills to integrate aspects of sustainability when tackling engineering problems. The approach, which has already been implemented across a number of different design and innovation modules, consists of two distinct phases. In the first, students are educated about sustainability and related issues. In the second phase, students are educated for sustainability and are taught to identify, define and solve problems so they can plan, develop and implement solutions to complex sustainability challenges/problems. Implementing this approach has raised questions, particularly in relation to helping students deal with conflicting requirements, understanding the limitations of their own knowledge, and the relationship between ethics and sustainability. Engineering educators will need to address such questions as they develop their approach(es) to sustainability education.

Keywords: sustainability education; multistage; mechanical design

A Teaching Framework for Engineering Risk Estimation under Climate Trends

87–98

Vijay Panchang, Jemerson P James, Pratiwi Fudlailah and Sashikant Nayak

Estimation of risk during the lifetime of a project is an integral component of engineering design. Often, the concept of the "return period", which relates to the realization of the risk, is taught in upper-level courses, especially in the context of structures experiencing random environmental loads. In recent years, it has been recognized that trends in the underlying data, in addition to the inherent randomness, may play an important role in estimating risks for engineering design. While the research community is attempting to accommodate this non-stationarity in risk estimation, the urgency arising from climate trends requires new graduates and practitioners to understand the methods involved. Under these conditions, the widely used concepts of return periods and the consequent risks to a structure has to be examined in a new light. Our goal is to develop a framework that can be used in teaching selected undergraduate courses, master's level courses, and professional continuing education courses to enable the student to make practical engineering calculations. Since the mathematical formulations can be intimidating, we demonstrate a simple Excel-based teaching framework that instructors can utilize to present the underlying ideas in an intuitive manner and to enable students and practitioners to easily implement the concepts. Attention is also devoted to communicating the results to concerned parties. Student performance data relating to two assignments over two years indicated that, while only 40% solved the first assignment correctly, owing to a better understanding with the passage of time, 65% of the students demonstrated full comprehension on a second assignment which was based on individualized datasets; the others received scores of 90% or higher. Thus, the approach provided here appears to be suitable for classroom education.

Keywords: return period; non-stationarity; risk

Innovative Concepts for Integrating Mathematics and Modelling Training in Industrial Design Engineering Program

99–107

José Antonio Pérez, Alvaro Deibe, José Ramón Méndez, Jon Solozabal, Pablo Fernández, Añitor Regueiro and Cristina Prado

In order to improve the expertise and skills of students and compensate the growing lack of interest towards mathematics in Industrial Design Engineering, during the last years several innovative teaching experiences have been developed, coordinating academic activities between the areas of Mathematics and Design Projects. These coordinated experiences allowed the introduction of advanced essential contents in parametric representation, numerical analysis and manufacturing in the first course, contents which are barely included in the curriculum of Industrial Design Engineering university degrees. Despite the issues and complexity of their planning and practical implementation, results have been excellent; transforming the perception of mathematics by students from a simple working tool to a stimulating new way of creation and inspiration to explore.

Keywords: industrial design engineering; design education; product design; mathematics learning; STEAM (Science, Technology, Engineering, Arts and Mathematics)

Rachel Xenia Chang, Isabel Ortiz-Marcos, Rocío Rodríguez-Rivero and Marly Monteiro de Carvalho

There has been an emerging interest in exploring the *influence* of individualism-collectivism and uncertainty avoidance cultural dimensions on risk perception at an individual level of analysis. This paper aims to evaluate the impact of both cultural dimensions on risk perception. For this purpose, a survey was conducted with 340 students; 214 Brazilian and 126 Spanish respondents participated. The data were evaluated using descriptive statistics and Fuzzy-set Quantitative Comparative Analysis (fsQCA) for hypotheses testing. Results demonstrate that collectivistic and uncertainty avoidance preferences negatively influence risk tolerance, leading to risk-avoidance behavior. The managerial contributions of this study focus on aspects that lead to a broader sense of the collective, social and environmental aspects. Furthermore, this study contributes to the academic literature by demonstrating how individualism-collectivism and uncertainty avoidance impacts risk perception.

Keywords: individualism-collectivism; uncertainty avoidance; risk perception; fsQCA, cultural dimensions

Making the Case for Applying Athletic Coaching to Support and Propagate Instructional Practices in Engineering Education 119–128

Renee M. Clark, Samuel J. Dickerson and Marc Christian

Leading scholars have indicated a lack of knowledge on *how* to propagate and sustain evidence-based instructional practices, such as active learning. However, they have identified social interactions as key for dissemination. Interestingly, the instructional coaching literature has drawn a direct connection between propagation of research-based practices and effective coaching of teachers. The authors have worked to propagate active learning and educational scholarship among instructors in their school of engineering. Their support model for this was informed by the change framework of Henderson and colleagues and consists of learning-community events, instructional coaching, classroom observation, student feedback, and instructor follow-up. Interestingly, the social focus of their model, including one-on-one coaching, was identified as a strength by the participating instructors. Preliminary results from this support program have been promising with respect to instructor participation, propagation of active learning and educational scholarship, and valuation by instructors. In this article however, the authors make a new argument for the infusion of athletic coaching to their support model for potential transformative outcomes. Despite the shared mission of athletic coaches and academic instructors to educate young adults, there is often little-to-no collaboration between them. However, given the origin of coaching in athletics, shouldn't instructional coaching be looking to athletic coaching for transformative insights and support? Along with making an argument for this unique paradigm, the authors suggest an exploratory case study approach for assessing the impact of athletic coaching within an engineering instructional support and propagation program. Our ultimate objective is to inspire and support other educators in adopting this potentially transformative model.

Keywords: coaching; instructional; athletic; interdisciplinary; propagation

Faculty Conceptions of Tensions in PBL Implementation in Early Undergraduate Engineering Education 129–141

Angela van Barneveld and Johannes Strobel

Problem-based learning (PBL) is used in upper-level and increasingly in earlier years of engineering education. By implementing PBL, comfortable routines are disrupted for both educators and students, creating tensions. Using a methodological framework of phenomenography, this study explored the variation in engineering educators' conception and experience of the tensions when implementing PBL in the first two years of undergraduate engineering education. Results revealed that engineering educators' experiences of implementing PBL in the first two years are described by three predominant tensions. Faculty experiences of the key tensions associated with the implementation of PBL and their conception of these tensions (student, instructor, institutional) play a critical role in the development of instructional strategies for incorporating PBL into the engineering curriculum in the early years. The findings of this study can inform the development of support structures and teaching development programs for engineering faculty.

Keywords: faculty understanding; first-year engineering; phenomenography; problem-based learning; sophomore engineering; tensions

Longitudinal Study of Engineering Student Persistence at the University of Colorado 142–153

Robert H. Davis and Brittany L. Bergstrom

To better understand why students leave engineering study and to identify strategies to increase persistence, first-year undergraduate cohorts that entered the College of Engineering and Applied Science at the University of Colorado Boulder (CU) in seven successive fall semesters were analyzed to determine their status at the start of their second, third, and fourth years following matriculation. On average, 85% of the entering freshman were still enrolled in the college ("stayers") as of the beginning of their 2nd year, decreasing to 75% at the beginning of their 3rd year and 70% at the beginning of their 4th year (including a very small number who graduated within three years). The rest were either enrolled in another school or college at CU ("transfers") or had left CU altogether ("leavers"). The outcomes data were then further analyzed to correlate factors such as course performance, gender, ethnicity, residency, and freshman living community on persistence in engineering. There is a strong correlation between poor performance in courses and departure from the college, yet over half of the students who left the college had performed well (as measured by overall GPAs of 2.5 or above or by no D, F or W grades in their first year). While women persisted in the college at nearly the same rate as men, those women who left were more likely to transfer to another school or college within CU, whereas the men who left the college were more likely to leave CU altogether. These and other key findings provide guidance for retention needs and strategies.

Keywords: student persistence; retention; data analytics

Learning and Instruction that Combine Multiple Levels of Abstraction in Engineering: Attitudes of Students and Faculty 154–162

Mohammed Ali Hadish, Shahar Kvatinsky and Aharon Gero

One type of thinking needed by engineers is abstract thinking, i.e., higher-order thinking that permits one to solve problems while maneuvering between several levels of complexity (levels of abstraction). In light of the above, the Faculty of Electrical and Computer Engineering (Technion – Israel Institute of Technology) decided to combine two introductory courses, focusing on different levels of abstraction, into a single undergraduate course "Digital Systems and Computer Structure" integrating multiple levels of abstraction, i.e., logical, micro-architecture and architecture levels. The study presented here characterized the attitudes of students and course faculty toward learning and instruction that combine several levels of abstraction. The research, which used quantitative and qualitative tools, involved 103 students and eight teaching staff members. According to the findings, students hold positive attitudes toward learning that incorporates multiple levels of abstraction, both cognitively and affectively, and the correlation between the components is positive, moderate, and significant. Students argue that this type of learning is interesting, provides a complete picture of computer systems, promotes higher-order thinking, and is relevant to industry work, but is also characterized by a high cognitive load. Course faculty claim that teaching that incorporates multiple levels of abstraction is enjoyable, imparts higher-order thinking among students but is very demanding. As for the behavioral aspect, the vast majority of students and instructors prefer learning and teaching that integrate multiple levels of abstraction over those that focus on a few levels.

Keywords: abstract thinking; students' attitudes; instructors' attitudes; digital systems; computer structure

Liu Xin Juan and Zhang Bin

Academic dishonesty (AD) in higher education institutions worldwide has become a significant concern. However, there are few related empirical and theoretical studies on schoolwork among engineering students. This study aimed to investigate the prevalence of academic dishonesty behaviors and the effectiveness of the extended Theory of Planned Behavior (TPB) in forecasting AD behaviors among Chinese engineering undergraduates at four public universities in China. This study employed a quantitative method and collected 474 responses via an online questionnaire among engineering undergraduates from four selected public universities in China. The results demonstrated that the participation rate of AD behaviors among engineering undergraduates at these four public universities is not very high. In the extended model, four predictive variables – attitude, control, norms, and justification are statistically efficient in predicting intention, which accounted for 65.6% of the variance. Meanwhile, intention, attitude, and norms together predicted 22.9% of the variance of behaviors. Attitude, norms, control, and justifications can influence AD behavior directly and indirectly through intentions. Targeted measures to decrease or deter intentions and behaviors of academic dishonesty are conducive to the sustainable development of integrity education.

Keywords: extended TPB; academic dishonesty behaviors; Chinese engineering undergraduates; education for sustainability

Fostering and Assessing the Systems Thinking of First-Year Engineering Students Using the System Architecture-Function-Purpose Framework

176–188

Rea Lavi, Lori Breslow, M. Mehdi Salek and Edward F. Crawley

As systems become more complex, demand for teaching systems thinking is increasing. To date, studies in undergraduate engineering education have not presented a pedagogical framework suitable for teaching systems thinking to first-year engineering students. We designed and applied such a framework, the System Architecture-Function-Purpose framework for technological systems, in a semester-long first-year remote course. Forty-four first-year students with undeclared majors studying at an engineering-centric university participated in this study. Participants practiced the framework as applied to multidisciplinary case studies. Participants carried out three in-class individual training assignments during weeks 4, 5, and 6. Each training assignment was followed by an out-of-class team assignment which expanded on the same case study. These assignments comprised the intervention component of the study, intended to improve students' systems thinking. The effectiveness of this intervention was evaluated during weeks 1 and 7 based on self-rated systems thinking (a) knowledge and ability, and (b) systems thinking as expressed in examples provided by participants. While self-rating improved from week 1 to 7, example assignment performance scores remained the same. We discuss future efforts for framework validation and provide suggestions for instructors.

Keywords: assessment; first-year education; remote learning; systems thinking; undergraduate education

Collaborative Engagement and Help-Seeking Behaviors in Engineering Asynchronous Online Discussions

189–207

Ruth Rothstein, Yonghee Lee, Edward J. Berger, Jeffrey Rhoads and Jennifer Deboer

With current online learning platform technology, we are now able to observe undergraduate student learning in many spaces outside of the formal classroom, including through the use of technologies like asynchronous online discussion forums (AODs). The help-seeking and knowledge building behaviors of students in these virtual learning spaces, and engineering students in particular, merit further investigation to elucidate the ways that discussion forums may support or hinder knowledge-building and collaborative processes that are important for engineering students' learning outcomes. This study employed qualitative content analysis of a large amount of discussion forum data from seven semesters of the same blended university-level engineering course to investigate the ways that students used the forum to engage with their peers and course material. Our findings indicate various collaborative engagement patterns existed to promote group knowledge acquisition (e.g., asking technical questions, providing technical answers, and challenging or validating those answers). We posit that these engagement patterns made the forum an effective computer-supported collaborative learning (CSCL) space for the community of users as a whole. We find further support for the role of social presence, or a sense of group cohesion, learners may feel when interacting on the forum, and the ways in which it may shape knowledge construction in blended learning environments. We provide a series of practical implications to engineering educators and AOD designers for optimizing the ways in which learning happens for engineering students on educational discussion forums.

Keywords: engineering; asynchronous online discussion forum; computer supported collaborative learning; content analysis; collaboration; group learning

Promoting Engineering Students' Learning: An Interdisciplinary Teaching Approach of Electronic Circuits

208–218

Beto Catz, Avinoam Kolodny and Aharon Gero

Interdisciplinarity, namely, combining two or more fields of knowledge around a central theme, allows students to observe the topic from several viewpoints and may foster their cognitive skills. Therefore, the Faculty of Electrical and Computer Engineering (Technion – Israel Institute of Technology) developed and implemented an interdisciplinary teaching approach of electronic circuits. This approach integrates the two main branches of electronics, i.e., analog electronics and digital electronics, which are traditionally taught separately in academia. The research described here examined whether this interdisciplinary approach has advanced learning compared to the traditional disciplinary way. The study, which used quantitative and qualitative tools, involved 156 junior electrical and computer engineering students. According to the findings, the analytical skills of students taught via the interdisciplinary approach were significantly higher than those of their peers who studied in the disciplinary way. Students who experienced interdisciplinary learning argued that it was interesting and natural, improved comprehension and analytic capabilities, but was also characterized by a high cognitive load. The preference for interdisciplinary learning was significantly higher among students who experienced it compared to their peers who were exposed to traditional learning.

Keywords: interdisciplinary education; academic achievement; attitudes; electronic circuits

Computer Simulation and Animation (CSA) for Learning Particle Dynamics: Force and Acceleration in Curvilinear Motion

219–227

Ning Fang and Yongqing Guo

Force and acceleration are two fundamental concepts in engineering dynamics, a second-year foundational course required in many undergraduate engineering programs. Research has shown that many students do not possess solid conceptual understanding and problem-solving skills when dealing with force and acceleration. In the present study, two new computer simulation and animation (CSA) learning modules are developed to enhance student learning of force and acceleration in curvilinear motion in particle dynamics, an essential part of engineering dynamics. Quantitative research has been conducted, involving a total of 286 engineering undergraduates in the comparison and intervention groups. Non-parametric statistical analysis of the collected data was conducted. The results show that the two CSA learning modules developed in the present study have a statistically significant effect on student learning. Student participants in the intervention group achieved 40%–44% average normalized learning gain; whilst those in the comparison group achieved only 4%–15% average normalized learning gain.

Keywords: computer simulation and animation (CSA); particle dynamics; force; acceleration; curvilinear motion

Güzin Tirkeş, Güler Kalem, Hürevren Kiliç and Nergiz Ercil Çağiltay

Among the numerous aspects of everyday life affected by the COVID-19 pandemic, education stands out as one of those deeply impacted. In this context within university settings, the ICT senior project courses were no exception either. This study presents the recommendations for a hybrid curriculum based on the online implementation of a senior project course in the ICT departments of an engineering faculty. The data were collected to better understand the impact of this re-structured course on 99 undergraduate IT students and their projects during three semesters, and later analyzed qualitatively and quantitatively to obtain some insights. The results indicate that, during the pandemic, the students adapted their senior project studies to the related restrictions by changing certain aspects related to the project, improving their teamwork, and increasing the level of communication. However, they also reported certain problems related to their overall psychology as well as social interactions. In light of the pandemic effect on the software industry towards remote working environments, further suggestions are provided to eliminate the drawbacks of remote working reported by the students and to equip them with the necessary skills. The resulting recommendations could be used by other higher-education institutions and be further adjusted for application in other disciplines.

Keywords: ICT senior/graduation project course; COVID-19 pandemic; virtual meetings; hybrid curriculum

Multi-Criteria Evaluation of eLearning Attributes using the Fuzzy TOPSIS Method

241–251

Martin Jaeger, Desmond Adair and Sayed Soleimani

Various models of evaluating eLearning system success have been identified in the past and the need for *effective* evaluation of eLearning systems has been highlighted during the COVID-19 pandemic. The purpose of the present work is to elicit how both academic staff and students (the evaluators) view the performance of eLearning attributes when being taught using an eLearning system. The attributes are ranked using a multi-criteria evaluation algorithm called the Fuzzy Technique for Order Preference by Similarity to the Ideal Solution (Fuzzy TOPSIS). Here, using linguistic-response expert questionnaires, a set of eLearning system attributes and a set of eLearning system criteria are evaluated. The Fuzzy TOPSIS algorithm yields weightings for each of the attributes which can then be ranked to arrive at the optimal solution in terms of how well they contributed to the success of the current eLearning system. IT service quality is found to rank highest, followed by technical system quality, information quality and finally the consideration of different learning styles. Large agreement is seen between academic staff and student evaluators, with minor disagreement between students of two different disciplines. As regards practical implications, it is shown from the rankings that the eLearning system must be re-organized and consideration of different learning styles must be improved. The Fuzzy TOPSIS method has been found to be a reliable and economic evaluation approach of eLearning systems, since it does not require large numbers of evaluators and provides a ranking of attributes which translate directly into priorities for improvement.

Keywords: eLearning; eLearning system; TOPSIS; multi-criteria evaluation; fuzzy numbers

Student Self-Efficacy and Satisfaction: A Comparative Analysis of Online and Onsite Versions of an Analog Electric Circuits Lab

252–262

Wesley Lawson and Jennifer L. Kouo

We present the design, operation, and analysis of an online introductory-level analog electric circuits course. The course is an adaptation of a sophomore-level onsite course taught in its current form at the University of Maryland, College Park for a decade and has both a traditional lecture component and an active-learning laboratory component. We compare the expectations, attitudes, and performance of the students whose lab sections were online to those students who took the traditional onsite lab. The study was performed across four sessions from the summer of 2020 through the summer of 2021 with a total of 111 students. The summer classes were 100% online, but the fall and spring semesters had a mix of onsite and online lab sections. A total of 34 students took the onsite version of the lab leaving 77 students in the online lab sections. Twenty-six percent of the students were female, Hispanic, or African American. The percentage of students passing the course was 88% both for the full cohort and for the underserved population. The percentage of online students passing the course was 92%. Student surveys probed the students' expectations, level of satisfaction, and self-efficacy and focus groups were conducted to help validate survey results. While onsite lab students had higher expectations and were more satisfied with their lab experience, the two cohorts reported similar feelings of self-efficacy. The post-course analyses helped to improve the online course from one semester to the next, but the quality of the interaction with the instructors and teaching assistants was found to have a significant impact on the students' responses.

Keywords: analog circuits; online education; laboratory; higher education

Impact of Work Experience on Engineering Graduate Students' Teamwork Skills, Knowledge, and Terminology Usage

263–276

Olivia Gettel, Diane L. Peters and Elizabeth Gross

Many studies seek to understand teamwork skill development, and teamwork is a core concept in engineering education. Whether teamwork skills are effectively developed in the classroom or whether additional training is needed, however, is not always clear. This study seeks to answer this question by examining the understanding and implementation of teamwork skills by two groups of engineering master's degree students. The first group is defined as Returners, individuals who spent five or more years in industry before returning to university to obtain a master's degree. The second group is defined as Direct Pathway students, who spent less than five years between degrees. Several comments in the data collected in a study comparing Returners and Direct Pathway students indicated a potential difference in how the two groups work in teams. Thus, this work sought to determine whether work experience has an impact on how teamwork skills are developed. A survey was completed by approximately 300 engineering master's degree students at multiple universities throughout the United States, and 41 students were interviewed. Fixed choice survey questions asked participants to rank their confidence in various team- and group-related activities. Free-response questions and interviews were used for further insight on teamwork skills and knowledge. Returners were more confident in their skills for every teamwork-related activity. Returners were also more likely to use the word "team" in survey responses, as opposed to Direct Pathway students who largely used "group." Interviews showed that group work is common in academia, whereas teamwork is a central concept of engineering in industry. Academic institutions should develop programs that better prepare students for teamwork in industry. Current programs focus primarily on group work, rather than teamwork. Significant differences exist in terminology used to describe multi-person collaboration depending on work experience levels and the collaborative context.

Keywords: team; teamwork; group; academia; engineering; industry