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A lecture-based theoretical approach is frequently utilized when teaching courses in electrical circuits and the educational learning objectives are often limited solely to content learning. This paper describes how a lecture-based electrical circuits' course was redesigned utilizing pedagogies of engagement to produce an environment that stimulates creativity and allows for the following additional learning objectives to be pursued: (1) improvement of hands-on skills, (2) increase in design abilities, and (3) teaming/collaboration proficiency. Educators are often deterred from pursuing these additional learning objectives in a large classroom or when there is lack of space and equipment. In this study, a "lab in a box" approach is outlined and shown to overcome these deterrents and foster an environment of student engagement. An inexpensive and easy-to-maintain portable kit was developed to enable approximately 300 undergraduate students each year to build and design electrical circuits. While teaching a course titled *ENGR 2431–DC Circuits* for years in a traditional large lecture-based classroom, the instructor was eager to adopt an alternative pedagogy to increase students' intrinsic motivation and overall engagement in the class. The expected benefits of the project in the near term were to increase student engagement and add three additional learning objectives to the course. After implementing the "lab in a box" project in a large classroom, survey data and observational experiences provided an indication that students are more engaged and in control of their learning.

Keywords: engineering education; electrical circuits; pedagogies of engagement; hands-on in a large classroom; project-based learning; object interaction

Based on in-depth qualitative interviews with student veterans in the United States pursuing Bachelor's degrees in engineering across four institutions, we present findings relating military leadership and its application to engineering education. Our findings address three themes: (1) how leadership skills are learned, (2) motivation to be a leader, and (3) translation into, and enactment of military leadership skills in, engineering education. The interviews show that leadership skills and experiences acquired in the military play an important role in the academic experiences and success of student veterans in engineering (SVEs). Findings can help inform strategies and programs to encourage more SVEs to translate their leadership skills to an academic setting in an asset-based framework. Providing leadership opportunities for SVEs in the classroom has the potential to increase their engagement in engineering, strengthen their pathways to professional engineering practice, and provide important role models of servant leadership for the other engineering undergraduates who work with them.

Keywords: military veterans; leadership; engineering students

Students' academic performance is stymied when there is a lack of motivation to learn. It is hypothesised that intrinsic motivational factors are more prevalent than extrinsic factors in civil engineering students with high academic performance and that motivation does not remain constant throughout a degree. Cognitive theory is utilised with a cross-sectional design to evaluate 148 students enrolled in a three year BSc. Civil Engineering program. Principal component analysis reduced twenty-two positive variables to five factors (Personal, Perfectionist, Parental/Family, Job/Career, and Social Acceptance) contributing towards student's overall motivation. Using ANOVA at a significance level of $p \leq 0.05$, the motivational factors that differed between academic years of study were Perfectionist Motivation and Job/Career Motivation. These differences provide a basis for the further examination of the time-varying nature of motivation. While intrinsic motivational variables were shown to have a more positive effect based on the mean responses, as a factor it was not wholly successful in predicting academic performance, rather extrinsic factor social acceptance accounted for high grade-point averages. Trends indicate motivational factors vary by age, gender, and local versus foreign origin. These result provide a greater understanding of precisely what impulses students are guided by during their studies and provide foundation for focus areas to be explored by educators.

Keywords: motivation; academic performance; cognitive theory; undergraduate student; civil engineering

Higher education institutions are increasingly offering opportunities for online learning, yet the issues of identifying students and verifying the authorship of their work limit the adoption of online assessment. Furthermore, little is known about the instructors' and students' background and confidence in e-assessment. This study analyzes students' and instructors' experiences, trust, and expectations regarding the use of an e-authentication system for e-assessment purposes. A total of 154 students and 12 instructors were surveyed, and two group interviews conducted, within the context of a pilot for a European project. The pilot consisted of testing several security mechanisms through diverse e-assessment activities in an online university course in digital systems. The results showed that participants had little experience with courses where all assessments were conducted online. Negative expectations of e-assessment (i.e., workload and time overload) were dispelled while ideas about the expected benefits were realized (i.e., flexibility, mobility and comfort). Attitudes toward e-assessment remained positive despite the technical difficulties that arose during the pilot. The use of security mechanisms was perceived as beneficial and opened up new opportunities for innovative practices in e-assessment but caused some mistrust or sense of invasiveness among participants. This study contributes to advancing the field of technology-enhanced assessment and understanding students' and instructors' perspectives on that matter.

Keywords: e-assessment; online education; security mechanisms; students' and teachers' perceptions

Concept inventories (CIs) have become popular assessment tools in science, technology, engineering, and mathematics education. Some researchers use CI scores when looking at differences in conceptual understanding or learning gains across demographic groups, but very few CIs have been evaluated for measurement bias or other aspects that threaten the fair assessment of learners. The most common psychometric evaluation models are shaped primarily by the majority demographic group, so these models can hide biases in the assessment against minority groups. The purpose of this study was to evaluate the extent to which the validity, reliability, and fairness evidence supports the use of the total score on a 12-item Abbreviated Dynamics Concept Inventory (aDCI) as a measure of a student's overall conceptual understanding of dynamics. Because of the strong relationship between the aDCI and the Force Concept Inventory, which has previously been shown to include item-level gender biases, we examined threats to fair measurement across gender scores of the aDCI. We employed an argument-based validation approach which tested: (1) the fit of a single-factor latent structure for the aDCI scores via a confirmatory factor analysis (CFA), (2) the difficulty and discrimination of each item using item response theory, (3) the correlation between the aDCI scores and similar measures of conceptual understanding, and (4) the differential item functioning of the aDCI items across gender groups via a multiple-group CFA. We found that one item had face-level construct validity concerns and two others were slightly biased against women. Possible sources of gender bias included the question's content and context. Our results suggest that the interpretation of a student's total aDCI score should consider the differential item functioning of two items across gender and the construct-alignment concerns of a third item. This work highlights the importance and challenge of designing inclusive assessments and validating them with fair psychometric models.

Keywords: concept inventory; validity; reliability; fairness; gender; engineering education; assessment bias

We report a new learning approach in collaborative learning-by doing, real-world team-based project in two ICT courses: Digital Systems and Computing Engineering, conducted at Universitat Politècnica de Catalunya. Data collected included: background information on students; course evaluations; measures of the knowledge and cross-knowledge of both disciplines taken before and after our SimulAVR project. SimulAVR integrates interdisciplinary knowledge by simulating via software a microcontroller and its implementation in VHDL. Our study is based on the analysis of the results of running the project for 3 years. After taking the simulAVR project, the students rated the interest in both courses higher.

Keywords: interdisciplinary projects; learning by doing; problem-based learning; collaborative work; teamwork; multidisciplinary approach; ICT; microcontrollers; simulation; digital systems; motivation; computing engineering

Undergraduate engineering students are expected to develop an understanding that engineering solutions can have global implications. Perceptions on engineering solutions by people from different cultures can be very different, and globally aware engineers need to understand and anticipate these perception differences. As engineering programs strive to instill the requisite learning to produce this outcome, a fundamental question to address is whether global awareness can be assessed as a part of engineering students' progress in the engineering curriculum. This article proposes and validates a new instrument, based on a developmental model—the Model of Domain Learning (MDL)—to gauge engineering students' growth in global awareness. Presented research responds to the following research questions: (i) Does engineering students' global awareness improve throughout their education? (ii) Do the expected relations among components of the MDL (i.e., knowledge, strategic processing, and interest) hold for the domain of global awareness? A total of 425 students, enrolled in 18 different engineering programs in a US land-grant university, participated in this study. The study findings supported that, (i) as they progress in their education, engineering students' knowledge, strategic processing, and interest increase in tandem for the domain of global awareness, (ii) the MDL can serve as a framework for assessing engineering students' development of global awareness.

Keywords: Model of Domain Learning; assessment; global awareness; undergraduate engineering

Although it is widely recognized that conceptual understanding is vital to effective engineering education and practice, both practicing engineers as well as students demonstrate misconceptions related to basic engineering concepts. And while a growing body of research has demonstrated the differences in the role and function of concepts across school and work, less is understood about the ways engineers in practice describe the concepts they use. The purpose of this research is to explore the way practicing engineers articulate their understanding of fundamental concepts in fluid dynamics. Using two independent samples, we administered the Fluid Mechanics Concept Inventory (FMCI) to one group of practicing civil engineers and used FMCI to conduct clinical interviews with the other. Our analysis focuses specifically on understanding of pressurized pipeline problems. We performed descriptive statistical analyses alongside the application of an *a priori* codebook informed by prior research with students. Misconceptions revealed through incorrect responses to FMCI are elaborated on by the qualitative clinical interviews. Findings suggest that, much like students, practicing civil engineers still harbor misconceptions concerning fundamental fluid mechanics concepts related to pressurized pipe flow problems. Engineers in this study relied on overly simplified relationships and inappropriately applied principles in ways that echo findings from similar research with students. Given the persistence of such misconceptions, it seems important to consider the meaning of these concepts both at work and in preparing students for work.

Keywords: fluid mechanics; conceptual knowledge; engineering practice; misconceptions

As a young discipline Computer Science suffers from a crisis of identity when trying to best approach research problems and conduct quality and rigorous scientific work. This is commonly handled by borrowing scientific methods from mature disciplines, such as Mathematics and Logic theories. However, whilst the object of investigation in Computer Science changes both the construction of theories describing it and the growing practical experience in its usage, accepted scientific methods do not respond well to interplaying with theoretical and practical approaches. Particularly, emergent interdisciplinary fields within Computer Science, such as Online Education, show no consensus in literature about well-defined methods to conduct systematic research, thus facing difficulties to deal with interdisciplinary research and methodological gaps. The ultimate goal of this study is to shed light on these difficulties whilst proposing methodological guidelines and good practices in order to foster sound research in the Online Education field.

Keywords: online education; learning engineering; engineering education; e-Learning; computer science; software engineering; research methodology; scientific methods; interdisciplinary research

Predicting student performance (PSP) is of great use from an educational perspective, especially for the at-risk students who need timely support to complete their study. Previous PSP studies have been mainly based on data from questionnaires and specific learning systems. Such data sources have some innate shortcomings. Instead, we used a novel data source, the massive students' campus card usage records, to predict at-risk students. This method has two advantages: convenience in data collection and ability to predict students' overall academic performance. However, as the original data are complex, large in scale and with a lot of noise, it is challenging to extract proper features from them. We adopted a four-step procedure for data preprocessing and the Naive Bayes model for performance prediction. Experiments showed that the proposed prediction model could identify about 70% of the at-risk students. Some features of the at-risk students were also discovered, which might help student counselors and educational researchers better understand the relationship between students' consumption behaviors and their academic performance.

Keywords: educational data mining; predicting student performance; campus card; feature selection; classification

All engineering students develop and mature through their four or more years in college as they prepare to become part of a socially impactful profession. Presently, students' ideas about how they will be socially responsible engineers in the future remains unknown. Understanding more about students' evolving ideas about how they plan to integrate their motivation to be socially responsible with their chosen profession can give insight into how to improve the alignment between students' personal and professional lives. This study includes four years of longitudinal interviews with engineering students. The interviews consisted mainly of questions regarding experiences with social responsibility, engineering, and the combination of the two. The interviews were analyzed using an Ethic of Care framework, which allowed for the students to be categorized into one of four types that emerged from the student responses. These types described how strongly students integrated social responsibility values with their motivation to pursue engineering. Each year, some students switched types and some left engineering altogether. Most engineering students seemed to settle on the idea that engineering improves society overall. For some, this was a major motivation, and for others it was a nice bonus of the profession. These results assist in developing the baseline for what students are experiencing and thinking through their years in college, and gives insight into how students are internalizing their experiences. The results also provide some guidance in developing an engineering educational experience that promotes a more socially responsible and caring career path.

Keywords: social responsibility; qualitative research; longitudinal; alignment; care; ethics

The shift of contemporary product design from being mono-disciplinary to transdisciplinary requires educational institutions to develop new educational methodologies to ensure their students are fully prepared for the new career and life-long challenges. This paper is a part of the study entitled Transdisciplinary Design Education for Engineering Undergraduates, which goal is to enhance engineering education by developing transdisciplinary teaching methodology and establishing a common engineering design process. This paper presents detailed results from the cognitive game task, based on the Bloom's Taxonomy Cognitive Domain and a general engineering design process, developed to access the design thinking of engineers. The general design process and its stages, application of Bloom's Taxonomy and a list of action verbs, and transdisciplinary teaching approach are discussed.

Keywords: engineering design education, transdisciplinary design, engineering design process, Bloom's Taxonomy

Master students at our institute were graduating without acceptable research proficiency. We intervened by shifting our research training from teaching-centred to student-centred, and from research-related subject content to research-related processes. We performed a mixed methods study aimed to confirm there was improved research proficiency without a negative trade-off for our students' engineering skills. Results indicated improvements to research proficiency, which our students were able to transfer to engineering-related learning activities to increase their ability to achieve engineering synthesis. This outcome was potentially supported by our courses including several perspectives on scientific knowledge production. This implies that research training, rather than having a negative effect on engineering skills, can be helpful in learning diametrically opposing aspects of thinking required by current engineering. As engineering education evolves towards more cross-disciplinary cooperation, this implies the need to pursue the increased opportunities for students to learn about different perspectives on knowledge production.

Keywords: engineering education; master's education; science education; research-teaching nexus

The current study aimed to investigate the use of higher-order thinking (HOT) skills by engineering students and to classify student profile groups according to the underlying constructs of HOT. We recruited 260 engineering students from six universities in South Korea. The data were analyzed in terms of the existing latent profiles and the chi-square test between the profile groups and their experience of different types of instruction. The latent profile analysis revealed that the use of HOT skills could be classified into four groups (i.e., a lower-order thinking group, a creative and argumentative group, an analytical and caring group, and a HOT group). A chi-square test between the four categorizations of HOT skill uses and instruction methods was not statistically significant. A majority of the students were classified in the HOT group. However, of the six constructs, the creativity skill was the least used, as opposed to skills that fell under other constructs. Therefore, supplementary instruction to fill this gap is suggested.

Keywords: engineering college students; higher-order thinking skills; latent profile analysis

A laboratory installation designed for simulating groundwater flow in homogeneous and isotropic unconfined aquifers between two rivers or parallel channels is described in this paper. The laboratory installation allows to visualize and to study the behaviour of the phreatic surface, to determine the saturated hydraulic conductivity, and to compare experimental data with analytical and numerical solutions of partial differential equation describing the groundwater flow in steady-state and transient conditions. The installation is simple to use and has been proven to be robust and useful in improving scientific knowledge on modelling principles of groundwater flow in saturated porous media.

Keywords: groundwater modelling; porous media; laboratory installation; educational tool

Design and entrepreneurship education have emerged as platforms for exposing students to 'real-world' project experiences, instilling skills to succeed in the professional market. Both entrepreneurship and design education share similar project-based, active learning pedagogies and claim to cultivate similar 21st century professional skills; however, minimal work has been conducted examining specific student professional outcomes in both entrepreneurship and design courses. Using pre-post survey data, our study explores the impact of two classes, entrepreneurship and biomedical engineering (BME) design, on students' perceived learning gains in three professional skills: Risk-Taking, Creative Self-Efficacy and Entrepreneurial Self-Efficacy (ESE). Results indicated that Entrepreneurship course students reported significant increases in Creative Self-Efficacy and ESE. BME design course students reported minor improvement in certain aspects of ESE. Neither course significantly impacted students' perceived Risk-Taking ability. These results indicate that while design and entrepreneurship courses share content and pedagogy, they have a differing impact on students' perceived skills. We explicate key differences between the courses and their impact on perceived professional skills, examining why design and entrepreneurship education may be unique and how students may benefit from both.

Keywords: design; entrepreneurship; risk-taking; creativity; self-efficacy; outcomes

Continuous quality improvement cycle is essential in educational systems allowing institutions to meet the evolving needs of the market. As such, it is required by all accreditation agencies. Curriculum revision is a critical step of this cycle. This study proposes a modelling paradigm to automate the design, analysis and improvement of curriculum. Based on proven theoretical principles, this novel graph-based approach captures both pre-requisite and cognitive dependencies among courses, enabling an optimal learning environment for students. The presented tool allows an easy and fast analysis of the impact of potential course revisions on all other courses, hence enabling a better continuous quality improvement process, thus providing benefits to many stakeholders in the education system, namely managers, instructors, students and employers. The proposed modelling paradigm is explained and illustrated on a capstone project course offered in the College of Computer Science and IT.

Keywords: accreditation; curriculum development; curriculum design; quality assurance; engineering education; automated tool

Given changing demographics among engineers and engineering students, increasing international teamwork, and growing awareness of the ways in which cultural and cognitive biases may impinge on engineering problem-solving to reach optimal solutions, *can a course providing an opportunity to learn about culture and diversity benefit engineers' training?* In 2015, the inaugural Expanding Engineering Limits course was offered to undergraduate and graduate students as a transnational course between Stanford University in the United States and RWTH Aachen University in Germany. The course was designed to introduce students to a variety of terms, concepts, and paradigms that could deepen their understanding of culture and diversity in engineering education and practice. In addition to classroom lectures, students from both RWTH Aachen University and Stanford University participated in a Design Thinking course developed by the two teams and realized at Stanford's Hasso Plattner Institute of Design and worked on group projects throughout the academic term, examining organizational and cultural change in transnational teams. Instructors employed several qualitative and quantitative course evaluation methods, including pre- and post-surveys to measure student change in key attitudinal domains, short in-class reflections and questionnaires to solicit student feedback, institution-level course evaluation forms, and data from students' final projects. Overall, results from these evaluation techniques indicated that the course informed students' thinking and knowledge about the importance of diversity and culture in engineering. Students saw the experiences of working together in a transnational project team as very beneficial for the understanding of cultures and diversity in a professional context. Evaluation findings suggest that the course's intended goals were met to a substantial degree. We propose that a course-based experience such as this one *can* benefit an engineer's training, and share recommendations and ''lessons learned'' for engineering educators and leaders.

Keywords: engineering education; design thinking; diversity; gender; social responsibility; interculturality; international cooperation; intersectionality

The National Science Foundation (NSF) of the United States of America has established a Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM) program to provide scholarships (financial aid) and increase academic success of low-income, academically talented students with demonstrated financial need who are pursuing associate, baccalaureate, or graduate degrees in STEM. This paper describes the overall framework of the NSF-funded S-STEM program at Utah State University, including program goals and student recruitment and selection. Over the past three-year project period, 31 students were awarded S-STEM scholarships. Students could renew their scholarships for up to 4 years. A detailed description of two co-curricular activities that were particularly designed and implemented for S-STEM students is provided. These activities include S-STEM industry seminars and a student design competition. The impacts of these activities are assessed through analysis of student comments and responses to questionnaire surveys. The assessment results show that both activities have a positive impact on S-STEM students. Four lessons learned from the program implementation are described to help engineering educators adopt these activities in their respective institutions.

Keywords: Scholarships in Science, Technology, Engineering and, Mathematics (S-STEM) Program; undergraduate engineering education; S-STEM industry seminars; student design competition; assessments

The impact of flipping an engineering course on student learning outcomes remains an open question because the literature presents a perplexing array of results. In this multi-year study, we evaluate the impact of flipping a first-year project-based engineering design course. We pose two questions: (1) Does a flipped project-based engineering design course produce different levels of mastery of engineering design process knowledge compared to the lecture version of the course? (2) Do students in the lecture class and flipped class achieve the same levels of design process knowledge when given tasks that range in difficulty? Three strands of data were used to assess design process knowledge: first drafts of team technical memos, pre- and post-critiques of a Gantt chart of a proposed design process, and an exam. Teams in the flipped classroom performed significantly better on the technical memos that evaluated solution ideas and established a testing plan, both of which required high-level cognitive capacities. However, no differences were found between lecture and flipped models for the exam or technical memo that established design criteria, which required low-level cognitive activities. The Gantt chart assessment produced mixed results. This study concludes that flipping a project-based design course can significantly improve student learning on more difficult tasks. We urge researchers and educators to consider the tasks and assignments given to students when drawing conclusions about the effectiveness of flipped pedagogy.

Keywords: flipped classroom; engineering design; technical memos; task difficulty

The labor markets of the information age have an urgent demand for engineering and technical workers. STEM education has evolved into a metadiscipline, which involves an integrated effort to eliminate the traditional barriers between different subjects. Recent studies have reported increased levels of STEM education in international science education at the preliminary education stage worldwide. However, STEM assessment studies have lacked systematic and comprehensive assessment standards. Therefore, this study included a series of pretest and posttest evaluation questionnaires. With multiple evaluation methods, this study analyzed the effects of the STEM courses. This paper assesses the effect of the STEM courses on a total of 693 students of a primary school in Beijing. The results can be used to establish a more systematic and perfect evaluation system for students' interdisciplinary learning ability. STEM courses have achieved certain positive effects on emotional attitudes toward STEM, subject cognition, engineering professional cognition and engineering design ability among the three grade students, particularly for middle-school students.

Keywords: STEM education; engineering design; interdisciplinary learning; ability assessment