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Many universities offer introductory engineering courses that can vary widely in content between institutions—even among sections within the same institution. The view into the underlying content in such courses is often obscured by the lack of a detailed syllabus and an incomplete description published in the University's catalog. Thus, assessment of a course sequence can be difficult due to the sheer volume of students and inconsistent content among sections. Moreover, the vagueness can affect transfer students, because awarding transfer credit implies a set of instructional objectives that the student may not have encountered. This project resulted in a classification scheme, or taxonomy, of topics commonly found in "Introduction to Engineering" courses. The taxonomy allows a mapping of potential course content to be achieved such that users can communicate their courses using a common tool. The investigators utilized a three-stage qualitative research design situated in the "purposes," "content," and "sequencing" constructs of Lattuca and Stark's model of an "Academic Plan." The first two stages involved a survey of 28 syllabi for "Introduction to Engineering" courses followed by culling topics from transcripts of 6 focus groups of 4 first-year instructors in a conference workshop using content analysis. A culminating three round Delphi study with 24 participants served to finalize the taxonomy. Course content centered around eight primary aspects that frame the taxonomy, each of which was broken down further to include more specific topics that might be found under them. Note that the taxonomy represents a list of topics that *may be* found in "Introduction to Engineering" (or similar) courses as opposed to a list of all topics that *should be* covered. Instructors can now use "The Introduction to Engineering Course Classification Scheme" as a tool to aid in communicating their courses by classifying it in terms of common course topics—a universal syllabus of sorts. Schools interested in alternative methods of awarding transfer credits or curriculum development for courses like "Introduction to Engineering" can be empowered to make decisions that are more informed using the taxonomy as a flexible artifact of their processes.

Keywords: first-year engineering; taxonomy; classification; introduction to engineering

This article examines the use of an alternative form of assessment for engineering design projects called adaptive comparative judgment (ACJ). The researchers employed an ACJ tool to evaluate undergraduate engineering student design projects in an effort to examine its' reliability, validity, and utility in comparison with traditional assessment techniques. The ACJ process employed multiple judges to compare the design artifacts of 16 first-year engineering majors. The authors conducted an analysis of the reliability and validity of the ACJ method compared to the traditional rubric used to evaluate the project and the performance data of each student's design prototype. For these design artifacts, ACJ demonstrated a strong alignment with traditional assessment methods ($r_s = 0.79$, $p < 0.01$). Yet, neither ACJ nor traditional assessment results were significantly correlated with the actual performance of the design prototype. Additionally, the findings indicate the amount of time each judge devotes to judging student work using ACJ does not significantly impact the reliability of their assessment.

Keywords: adaptive comparative judgment; engineering design assessment; freshman engineering; problem-based learning

This paper presents a web application designed to support the teaching of basic 3D computer graphics concepts. This tool is aimed at introductory courses of computer graphics in the context of engineering studies. Through the web platform, the teacher configures and proposes interactively exercises related to the main 3D concepts studied in this kind of course. The student accesses the exercises through the web application and configures a solution, also visually and interactively, using the tool. Then the teacher can visualize the solutions given by the students and compare them with the right solution in a 3D environment. In addition, the platform provides an automatic pre-assessment of the exercises, which can be adopted by the professor or modified based on the visual revision. The tool has already been used in the classroom and it was assessed by analyzing both the experience of use and the relation between students' marks and the number of interactive exercises performed. The results obtained suggest that using the application is a positive factor to obtain better marks, regardless the students' ability or competence. The application is available via the link: http://www4.ujaen.es/~demiras/cgex.

Keywords: interactive troubleshooting; computer graphics teaching; WebGL; interactive learning environments

The presented research explores four years of newcomer engineering students at *FEUP*, one of the largest faculties of engineering in Portugal. The students are surveyed in a mandatory course common to all engineering programs at the mentioned faculty, totalling an involvement of about four thousand. This research explores the perceptions of 1198 newcomer students regarding learning and satisfaction, workload, integration into academic work environment and institutional support whilst trying to find gender differences regarding the following variables: engineering program, academic year and change of residence. The questionnaire used in the presented research was validated and its internal consistency was excellent. The findings reveal that students' perceptions on learning and satisfaction as well as on institutional support (two out of four factors) are consistently similar between genders throughout the four years of the study. The differences found between male and female students on integration and workload, however consistent, are small if not marginal. The study is significant because it shows the relevance of the optimization efforts for integration (in the academic work environment) introduced in a mandatory course at the start of engineering degrees in order to bridge the gap between male and female students. This research shows that we are walking towards gender equality in engineering, but we feel that there is still some effort to be done, namely through inspiring scholars to analyse and act upon academic contexts and higher education governance without prejudice and with an open mind: a commitment that is as hard as necessary.

Keywords: engineering; higher education; gender equality; first year integration; learning; institutional support

At its core, engineering and similar disciplines rely strongly on technical innovation to design and develop creative solutions to complex problems. However, for novice engineering students, conceptualizing engineering design activities is not an easy task. To do so, they must overcome cognitive blocks to facilitate unique and adequate engineering design solutions. This effect may be compounded when engineering design projects centered around service learning are introduced. The intent of this study was to explore if and what types of conceptual blocks may be present among novice engineering students when design heuristic cues are provided in the classroom. Findings suggest that using classroom interventions around design heuristic, students had a difficult time ''shaking off'' their conceptual blocks to the design solution. Primarily, communicative and perceptual blocks were found to predominate among novice engineering student groups.

Keywords: engineering design; design heuristics; conceptual blocks; service learning; first year curriculum

This study is to explore characteristics of the first-time-in-college (FTIC) students and first-time-transfer (FTT) students and compare them in terms of their demographics, the first-year engineering (FYE) common course credits, and graduation outcomes. The 2006 cohort students' course credits and graduation status in engineering at a large southwest public university were tracked for 17 semesters through the data retrieved from the university archive. Descriptive statistics were used to identify trends in the data from 1,989 FTIC versus 282 FTT students and inferential statistics were applied to check statistically significant differences between two groups and among subgroups. Apparent differences existed between FTIC and FTT students: FTT students showed comparable cumulative GPAs to FTIC students and better graduation outcomes, such as higher six-year graduation rates and shorter time-to-graduation in engineering than FTIC students. Considering the same learning environment after entrance to the institution, the better academic outcomes of FTT students imply unique success factors other than the difference in academic maturity. Therefore, identification of these unique success factors and reconstruction of each student population support systems can facilitate the success of both FTIC and FTT students.

Keywords: engineering students; transfer students; first-year engineering course, graduation rates

In understanding undergraduate students' success in college, their choice of career path must be fully understood. Different paths are appropriate for different students, and even a student may not fully grasp what will work best for them. Understanding the mechanisms behind a successful choice in college major is important for several reasons. Retention is necessary for the continued health of engineering programs. One of the earliest steps in this career path is selecting a major. Research has been done investigating major selection across all majors, and even focusing on STEM careers. This research has frequently overlooked the broad variety present in engineering majors with very limited research conducted that distinguishes between one engineering major and another. This paper seeks to address this absence by surveying engineering students from several different majors at three different institutions. The data for this paper was gathered using surveys of first year engineers at three dissimilar institutions. The survey data examined were open-response questions. These questions asked students to describe how they viewed specific engineering career paths. It is the goal of analyzing these responses to gain better insight into the student perception of various engineering majors. The data was coded through an inductive coding process. This coding process resulted in nine unique codes. The codes were analyzed to allow broader trends to surface. The results of this analysis have shown that not only do students in different engineering majors view these disciplines differently, but also that students at these different institutions view engineering differently.

Keywords: major selection; qualitative; first-year engineering

Mathematical modeling involving algebraic representations plays a crucial role in the problem-solving process and is an integral component of engineering practice. Graduates from science and engineering backgrounds are often recruited to teach engineering-inspired K-12 mathematics courses. However, due to the expert blind spot (EBS), teachers with expert-level content knowledge might not be able to teach as effectively as expected in their area of expertise. In this article, we report the findings of our study examining EBS among pre-service and in-service teachers engaged in an engineering-inspired teacher training program involving algebraic representational problems. The participants performed a ranking task where they ranked six problems in accordance with the ease or difficulty they felt that students enrolled in a beginner level algebra course would experience when solving them. In addition, an open-ended question asked a representative subset of the participants about their assumptions and explanations behind their indicated rankings. We found no significant differences in the mean scores between pre-service and in-service teachers for all of the six ranking task problems. This suggests that teaching experience does not have an effect on the perceptions of algebraic problem difficulty. These findings replicate and extend the EBS hypothesis that it is well-developed subject matter knowledge specifically that leads high content knowledge pre-service and in-service educators to inaccurately predict student's problem-solving difficulty. The findings suggest that EBS about algebraic problems is resilient to change in spite of teaching experience and training. Implications for K-12 engineering education and STEM integration are discussed.

Keywords: K-12 engineering education; teacher training, expert blind spot

Numerous pre-college engineering opportunities for K-12 students exist, including summer engineering programs at universities, engineering courses in high schools, and summer internships within industry. While these programs have been shown to increase student enrollment in engineering, the lasting effect of background factors on engineering identity, self-efficacy, and retention has not yet been examined. The goal of this mixed-methods investigation is to investigate how and to what degree background factors affect student success in engineering. We surveyed and analyzed 98 aerospace engineering students' self-reported background factors, engineering identity, and engineering self-efficacy. Student information such as GPA, retention information, demographics, standardized test scores, and initial major of study were analyzed with the students' self-reported data to determine significant factors. Our study used aerospace engineering students to investigate how background factors impact success factors (i.e., retention, GPA, engineering identity, and self-efficacy) in engineering. We found that having any single positive engineering pre-collegiate experience impacted success factors, with the most influential experience on success to be school experiences (e.g., high school engineering classes). This work establishes a framework, which can be used to conduct further examinations of background factors and success, which can inform the creation of pre-collegiate programs and curricula.

Keywords: survey; background factors; identity; retention

Research from the past 10 years suggests that students continue to have difficultly mastering statics content commonly required in engineering curricula. Even when students succeed in demonstrating procedural knowledge, they often still lack a deep understanding of core concepts. In this mixed methods study, we explore the potential of a writing-to-learn assignment to enhance students' conceptual learning in statics. Results from a quantitative analysis of exam grades for 345 students show little difference between experimental and control sections, but results from nine qualitative interviews with students highlight four different metacognitive activities they applied to the writing-to-learn assignment. The wide variation in students' approaches to this intervention, coupled with the emerging metacognitive acts, can be used to guide the development of more effective interventions.

Keywords: statics, writing-to-learn, conceptual knowledge, metacognition

This article reviews the concepts of different authors about creativity, creating a framework for reflection from an interactionist perspective about the components involved in the creative and innovative development of people and their influence in the education of an engineer, from the memes, the domain, the field and the individual. An analysis including the variables that strengthen or weaken the creativity within a sociocultural context is performed; in this sense, the elements of analysis involved in the development of creative processes are taken into account.

Keywords: creativity; domain; field; individual; interactionist approach; memes

As awareness grows about how difficult it is to increase the use of research-based instructional strategies (RBIS) among engineering faculty, we must develop a better understanding of not only what RBIS work, but also how they might fail when used by inexperienced practitioners. We conducted an effectiveness study to explore whether the course design and targeted outcomes of one RBIS—an intrinsic motivation course conversion—were maintained after control of a converted course was turned over from the designing research team to a new set of instructors. The study was conducted as an amplified secondary analysis, combining data collected from multiple offerings of the converted course. The study triangulates data from course artifacts such as course syllabi and assignments, motivation surveys from 352 students, and post-course interviews with 27 students. Analysis of course artifacts revealed a high fidelity of implementation. Analysis of surveys and interviews revealed that small changes in the team formation process (a shift of project selection from before teams are formed to after teams are formed) for students' projects significantly undermined students' intrinsic motivation to learn—a core targeted outcome of this RBIS. We found that small changes in implementation can undermine the targeted outcomes for the intrinsic motivation course conversion. The documentation and promotion of RBIS must carefully consider how to support faculty through what may be the inevitable shortcomings in achieving the targeted outcomes of RBIS as the result of small changes in implementation.

Keywords: research-based instructional strategies; fidelity of implementation; motivation; team-based learning; effectiveness study

A Research Experiences for Undergraduates (REU) Site on Interdisciplinary Water Science and Engineering was established in 2007 and has been implemented for nine years at Virginia Tech. The goal is to engage undergraduate students (REU fellows) in research activities related to critical water-related issues and challenges in the U.S. and around the world. As of 2016, 85 undergraduate researchers representing 55+ academic institutions in the U.S. have participated in this ten-week interdisciplinary research program. The accomplishments of the site are summarized in this paper. The research contributions of the undergraduate researchers have been documented in 50 conference and journal publications. Program evaluation results show that the site led the REU fellows to gain interdisciplinary research experiences, improve their knowledge and understanding about graduate school and its expectations, gain several professional and academic skills, and grow as independent researchers. Further, 86% of the site alumni pursued/plan to pursue graduate education, and 75% of them are pursuing or plan to pursue research careers in science and engineering. The lessons learned by the investigators are also noted.

Keywords: REU; undergraduate research; interdisciplinary; water; evaluation; alumni perceptions

Student-centered learning is known to lead to greater student knowledge gains and conceptual understanding. In practice, implementation of these approaches can vary from the ideal implementation as defined by the original developer, leading to differences in student outcomes compared to what might be expected. Fidelity of implementation, i.e., the extent to which key practices of a pedagogical approach are used, must be considered in understanding how student-centered pedagogies impact students. In this mixed method study, we examined how Process Oriented Guided Inquiry Learning (POGIL) was implemented across diverse institutional contexts and how those implementations affected students' conceptual understanding. The domains of curricula framework allowed us to understand how the curriculum as practiced by instructors and experienced by students differed from the ideal curriculum as originally designed. Our results show that implementation is impacted by the particular circumstances of a classroom, and that differences in implementation can affect the benefits to students. We conclude that fidelity of implementation needs to be taken into account when considering the effectiveness of any pedagogy.

Keywords: active learning, student-centered learning, guided inquiry, POGIL, fidelity of implementation

The future of learning is being revolutionized by challenge based learning (CBL), where academia offers solutions to real life challenges. Unfortunately, in developing countries academia overlook the importance of involving stakeholders who are the prospective owners of the solutions developed. This is because of the weak link between academic institutions and industry in research and development activities. However, to solve real life challenges faced by the society the researchers need to work closely and continuously with the targeted community for them to get the sense of ownership and for the solutions to take into account all relevant factors. This paper presents the impacts realized when eight stakeholders were fully involved from identification to developing solutions of the challenges facing the electrical power sector in Tanzania which is wholly managed by a public utility company TANESCO from generation to distribution. Challenge based courses introduced in taught PhD and MSc programs were used to create the necessary skills but also to evaluate the effectiveness of the approach in realizing the intended objectives. Nine PhD and six MSc students were involved. The stakeholders' involvement helped the research students to align the identification of the challenges to be in line with societal perception rather being purely scientific and/or technical like excessive reactive power or skin effect and to work in multidisciplinary teams. This paper presents the process adopted in real life challenges identification, the proposed solutions to the identified challenges and how academia can link with industry in solving real-life problems facing the society, in particular the higher learning institutions in developing countries.

Keywords: challenge based learning; curricula; smart grid; engaging stakeholders; challenge driven education

The aim of this study was to investigate the effects of lab activity gamification on students' motivation, engagement, and learning outcome based on students' performance and students' perspective. This study was an extension of our previous studies, which only considered the data from gamification systems, leaving several open questions about students' perspective. Two types of websites, Gamification (GM) and Non-gamification (NG) were used. While the GM website included game elements such as a Badge System, Score, Avatar, Leaderboard, Level, and Feedback (Notification), the NG website was a traditional website without game elements. In these websites, students conducted two main activities: creating their own questions (MCQs) and answering questions authored by classmates. Students were asked to complete the questionnaire regarding active learning, game elements, and motivation. Several statistical analyses were conducted to test four hypotheses, and results indicated support for all hypotheses. The results suggest that the application of gamification in engineering lab activities as a supporting tool has a positive effect on students' motivation, engagement, and learning outcome based on the consistency between students' performance in and subjective satisfaction with the gamification system. In addition, the results of frequency analysis indicate that 80% of students were motivated by "Ranking" and "Score" and 50% of students felt fun due to "Badges", "Feedback", and "Avatar". Students chose "Ranking" and "Score" as the game elements to be retained in the new gamification system.

Keywords: gamification; active learning; engineering lab; game elements

The objective of this study is to choose the teaching methods that have the greatest influence on the formation of the egresses entrepreneurial profile. This study was structured based on the descriptive research model and, for the choice of teaching methods, the ELECTRE I multicriteria decision support method (AMD) was used. Data analysis revealed that, according to the experts' perception, Coaching (MET-14) is the common method for the development of the entrepreneurial profile. The study enriches the existing literature on entrepreneurship education, broadening the knowledge about which teaching methods influence the egresses profile. The small sample does not allow generalizations.

Keywords: entrepreneurship; teaching; entrepreneurship education; systematic review; survey multicriteria decision aid; ELECTRE I

The aim of the study is to investigate the relationships between the affective learning attributes and academic achievement among engineering students. The affective learning attributes of interest were self-efficacy, attitude towards engineering, and student's engagement. A survey was conducted on first year students from the engineering diploma programme in a Malaysia technical university. The survey was administrated to 382 voluntarily participating students (n = 382). The affective learning attributes were assessed using existing instruments namely the Self-efficacy and Study Skills Questionnaire (SESS) for measuring self-efficacy, the Pittsburgh Freshman Engineering Attitudes Scale (PFEAS) for measuring attitude towards engineering, and Student Engagement Instrument (SEI) for measuring student's engagement. Academic achievement was assessed using the mid-term examination marks. To determine the associations among study variables correlational research design was used. The results showed a statistically significant positive correlation among the selected psychological variables and academic achievement scores under study. Attitude towards engineering and student engagement seems to be an important factor in predicting academic achievement among engineering students.

Keywords: self-efficacy, attitude towards engineering, student engagement and academic achievement

The purpose of this study is to analyze the impact of participation and communication of students in co-creation within the context of Higher Education institutions. This co-creation approach is evaluated as an alternative in engineering education, being useful for leading the educational process, research activities, administration support, and the community-industry relationship. A previous literature review was carried out to identify the theoretical confirmation of the relationship between the identified parameters (communication, participation, and co-creation), and a questionnaire was applied to 325 engineering students from 12 Ecuadorian universities with the objective of studying their behavior toward collaborative practices. The principal statistical tools used were exploratory and confirmatory factor analysis and structural equation model. The results verify that engineering student participation and communication have a significant and positive influence on co-creation as a generator of student satisfaction, especially in the study context. A co-creation vision at higher education—from the perspective that students are the center of the learning process—reinforces the education quality principles in an innovative way. The article concludes with the different managerial implications of the study, including the effectiveness of creating participation and communication channels between the university and engineering students with the objective of promoting co-creation as a managerial alternative.

Keywords: engineering students; co-creation; higher education; participation; communication; structural equation modeling

The present study aims to investigate possible perception gap between fresh engineering graduates and their employers about essential skills required for getting a job. Data were collected from 129 industrial employers and 812 final year engineering students from all over Pakistan with the help of a questionnaire adapted from Secretary's Commission on Achieving Necessary Skills (SCANS) comprising 36 questions categorized into eight broader areas. Data analysis reveals that wide gap exists between the perceptions of both, as employers give more importance to skills like creativity, communication, interpersonal, decision making and problem solving, while engineering graduates perceive that their technical skills would play a major role in getting them jobs. Strong correlation is observed between students' ranking of skills and their competence level in respective skills. Consequently, students' un-employment time increases causing concern among students, parents and the students' academic institutions. This situation becomes more alarming in a developing country like Pakistan, where unemployment has already touched 8.3%, the highest in last 13 years. Findings of this study can guide the management of engineering universities to better align their engineering programs with employer's requirements and create awareness among students about the importance of soft skills in their professional career.

Keywords: engineering education; employability skills; perception gap; engineering graduates

Because of the wide application of cryptographic mechanisms in private and business environments, a cryptography course at many universities has the great importance today. An undergraduate cryptography course is mathematically demanding, and it is quite difficult for students with poor background to follow the course syllabus. This paper presents the use of interactive software in demonstrating basic cryptology principles in modern cryptography. The teaching methodology applied fosters students experimental work and engages students in discussions to resolve problems. The data are taken in three consecutive school years (around 150 participants), when we used to apply ordinary teaching practices, and when we switched to the interactive teaching approach. The assessment method was the attendance of students in the classroom, which has increased significantly during the semester. At the grade level of the student we noticed better grade distribution, with higher average grade.

Keywords: cryptography; educational software; interactive teaching

Even novice engineers and non-technical students can design and build an Internet of Things (IoT) prototype in four days. We present a setup for rapid IoT prototyping in a classroom, identify necessary skills and combine these to a workshop that allows students to turn their ideas into prototypes. Our approach enables fast prototyping cycle, using a common and well-established development board and a computer. Arduino Uno is used for device prototyping and a Python program running on the same computer handles the needed Internet communications. A web server handles device and web client connectivity, logging and data monitoring. The method makes it possible to learn the needed basic skills in manageable steps, allowing students to focus on the actual prototype instead of struggling with the wireless and Internet communication problems. After the prototyping phase, the device can be ported to inexpensive and small ESP8266 based microcontroller. Compared to developing IoT prototypes directly with ESP8266, the setup presented is considerably faster. The whole process is based on free software tools which provides a possibility to utilize prototypes commercially, without a risk of a third party changing or discontinuing services. We arranged an experimental four-day workshop for university students (n = 19) from diverse backgrounds and varying levels of technical skills. All teams successfully built a working prototype based on their own ideas. Student self-assessment of programming skills was noticeably improved during the course. We later repeated the experiment with another group (n = 27) in a university of applied sciences, getting similar results. Our results indicate that this method is effective for learning IoT prototyping skills in a short time.

Keywords: embedded systems; ESP8266; free software; Internet of Things (IoT); rapid prototyping; novice engineering education

Lower global warming potential (GWP) refrigerants must be used in refrigeration education to integrate the environmentally responsible engineering principles in class. However, most of the refrigeration educational laboratories are still using hydrofluorocarbons (HFCs) as working fluids, which are considered as greenhouse gases. This paper shows the procedure to adapt the new refrigerant R513A in a refrigeration system used for a cooling capacity educational laboratory. First, the paper describes the organization of the laboratory session, and the characteristics of the different methods of cooling capacity calculation taught to the master's degree students. Then, the benefits of including new sensors in the experimental setup to obtain more accurate results are explained. Later, accurate new graphics and an equation to calculate the R513A cooling capacity are provided. Finally, the educational aspects worked with the students in this session, and each cooling capacity method are assessed. The procedure explained in this paper can be used as a guide for introducing lower GWP refrigerants in similar educational refrigeration laboratories.

Keywords: climate change; refrigeration; lower GWP mixtures; R513A; R134a

Gauge Repeatability and Reproducibility (Gauge R&R) is a useful skill needed in industry. Engineers rely on data to do analysis such as finding the root cause of a problem. Before data collection, the measurement system used to collect data must be analyzed first. Gauge R&R is a measurement system analysis (MSA) tool. This paper discusses the learning of Gauge R&R by engineering technology students. A laboratory exercise followed the introduction of the concept in a lecture. Students were tasked to create an Excel program to implement the Gauge R&R analysis. Test data were collected and analyzed using the Excel program they created. Gauge R&R was used as a tool for finding the root cause of a problem where the resistance measurement data were inconsistent. The learning module of a combination of lecture, laboratory, and data analysis worked well for engineering technology students. Self-evaluations before and after the learning module from eighty three participants indicate that students believed that they learned the subject well.

Keywords: Gauge R&R; root cause analysis; six sigma; student learning