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## Contents

## Contributions in: Project-Based Learning, Creativity, Internship, Apprenticeship Programs, Final Year Projects, Engineering Identity, Mathematics Self-Efficacy, Motivation, Life-Long Learning, Global and Cross-Cultural Experiences, Language as a Barrier, Remote Laboratories, Solid Mechanics, Electrical Machines, and Flight Mechanics



In this paper, we explore how engineering students are motivated to develop group creativity in a Problem and Project-Based Learning (PBL) environment. Theoretically, we take a social cultural approach to group creativity and emphasize the influences of a learning environment on student motivation in group creativity development. Empirically, a case study was carried out on a student satellite project in the Department of Electronic System at Aalborg University in Denmark, by using qualitative methods including interviews and observation. The findings show that student motivation is stimulated in multiple ways in a PBL environment, such as formal and informal group discussions, regular supervisor meetings and sharing leadership. Furthermore, factors such as common goals, support of peers and openness stimulate motivation. However, the students think that a time schedule is a barrier to group creativity. Thus, the supervisors are encouraged to be more aware of the complex relationships between student, teacher and task and the student response.

**Keywords:** group creativity; motivation; problem and project-based learning; engineering education



This paper presents a case study about the application of a project-based learning approach. In this case study, software development projects are performed by the students, using historical software development methods in order to demonstrate evolution of the subject. The presented case study differs from others reported in the literature in its utilization of historical methods for project execution. Getting feedback and reaction of students and assessing the success of the project-based learning implementation employed are the main objectives of the case study. Concluding the case study, critical points concerning this project-based learning implementation are identified and recommendations for similar implementations are mentioned.

**Keywords:** project-based learning; software engineering; software development standard



This paper presents a project-based active and collaborative learning approach to improving the technical and professional skills of engineering students. The approach includes three integrated tasks that students develop and design, rather than simply use them. Task 1 focuses on developing a computer simulation program for machining; Task 2 on developing the associated business plan; and Task 3 on the written and oral presentation of the project. Two examples of student projects are provided to demonstrate what and how students learned from their projects. The students' attitudes and experiences with their projects were assessed with a Likert-scaled survey questionnaire. The assessment showed that more than 80% of students responded that the overall experience with their projects was 'positive' or very 'positive', and they 'agreed' or 'very agreed' that their projects enhanced their teamwork and communication skills, business knowledge, and entrepreneurship skills.

**Keywords:** technical skills; professional skills; project-based learning; active learning; collaborative learning



The purpose of this study is to develop a blended TRIZ (Teoriya Resheniya Izobretatelskikh Zadatch) creative learning system model and framework that can be used to construct a blended TRIZ creative learning internet platform. This study uses literature analysis to summarize and construct the items included in the blended TRIZ creative learning platform and develop an expert questionnaire. The results of the expert questionnaire are analyzed statistically to develop the blended TRIZ creative learning system model. This model includes the system's development objectives, design, and mechanisms; the TRIZ framework; and the platform functions used to construct the blended TRIZ creative learning platform. This platform is then used to improve the quality of creative instruction and cultivate an appreciation for innovation among students, ultimately enhancing their creative abilities.

**Keywords:** blended learning; TRIZ; creative learning; learning platform



World-class universities have been recognized for their intellectual contributions, among which are the products and outcomes of their research, the impact these products have on the technological and economic development of regions of influence, as well as the education of researchers. Tecnológico de Monterrey is promoting research education among undergraduate students. The Internship in Research and Innovation Program (IRIP) was developed to instill those students with the skills and a motivation to include research and innovation as part of their curriculum. IRIP is a component of the Knowledge-based Development (KBD) model at Tecnológico de Monterrey, one of the central strategies that are consolidating it as a world-class teaching, research and entrepreneurial university. Different outcomes have been achieved since IRIP began, with close relations with the research groups

called Research Chairs. The results of the research include international publications, technical developments, innovations and patents, industrial research projects, and an increase in the training of researchers. The purpose of this paper is to present the conceptual and operational model of IRIP as an approach that, using Research-Based Learning (RBL) techniques, facilitates the integration of undergraduate students in research activities. After a summary and comparison of how research activities with undergraduate students are promoted in the top ranked universities, the different approaches (stand-alone, attachment and inserted) that a university can follow for integrating RBL into the undergraduate curriculum are discussed.

**Keywords:** research at undergraduate level, research-based learning, innovative educational models, Tecnológico de Monterrey



This paper presents some findings resulting from a four-year research aiming to identify what competence are developed by students following an apprenticeship program in engineering and what the developmental steps are in conjunction with the curriculum. The main findings presented here suggest: 1) that competence has three dimensions; 2) that the competence framework of an engineer has five main components; 3) that there are four main steps that comprise the competence development framework; 4) and that building competence results from three different and interlocking processes. Our competence framework is then discussed by comparing our graduates' profile with those of other engineers in France, as well as with existing international standards for professional engineers.

**Keywords:** competence of an engineer; competence development, apprenticeship program



This paper presents a new portfolio-based methodology for supervising the Final Year Project (FYP) in Engineering studies at the Escola Politècnica Superior (EPS) at the Universitat de Lleida (UdL). The main aim of the portfolio methodology, or learning-folder, is to maintain the students' motivation throughout the FYP process, keeping their stress level within advisable limits and increasing the student–teacher interaction. Thus, the students' well-being is improved and, as a consequence, the FYP completion rate rises. In order to achieve this goal, the proposed methodology emphasises the following aspects: (1) put in place a continuous outcome-based assessment, (2) plan and schedule periodic face-to-face meetings and (3) motivate the students to think about their own incentives. This methodology was implemented in a web-based tool, over the Sakai virtual campus. In order to compare our methodology with the traditional one, an evaluation was carried out during the 2008–09 and 2009–10 courses with a control group of 40 students and 11 teachers. The experimental results have shown that a high percentage of students who used the portfolio finished their FYPs within the time envisaged in the curricula plan. They also obtained higher marks in the majority of evaluated skills and planned their leisure time better.

**Keywords:** personal well-being; portfolio; final year project; learning outcomes



This work indicates the importance of the Final Year Project (FYP) in the strengthening of competences of engineering students.

The study also shows which personal competences of students are reinforced most during the FYP process, including the preparation, elaboration, presentation and defence stages. In order to gather information on this subject, a survey was conducted at two different Spanish technical universities—one public and one private—and a comparative analysis was performed of the questionnaires collected. The competence model considered is that used by the Accreditation Board for Engineering and Technology (ABET), since the official title of the public university has been accredited by this model.

The results indicate which personal and professional competences of students are reinforced well by undertaking the FYP. Any significant differences in response by university are explained in the study. For validation purposes, the results were contrasted with the instructor's perspective using the triangulation methodology.

Finally, the conclusions drawn will permit the design of new study plans to cope more effectively with the challenges of the FYP in the new Bologna framework.

**Keywords:** final year project; ABET competences; engineering education



This quantitative study investigated the relationship between cognitive self-appraisal (CSA) and cognitive self-management (CSM), and the level of problem difficulty for electrical-computer engineering, mechanical engineering, and computer science students working on their senior design projects. The study also evaluated metacognitive differences among the three groups. The study involved 168 engineering students working on 60 different design projects and 3 engineering professors who advised the students and evaluated the level of difficulty of the projects. Two Likert-scale survey instruments were used: Engineering Design Project Inventory (EDPI) for assessing students' CSA and CSM, and Rubric for Rating Students' Design Project (RRSDP) for evaluating the level of difficulty of the design projects. Statistical tests revealed (a) the existence of a significant relationship between students' cognitive self-appraisal and self-management, (b) the absence of a significant relationship between students' metacognition and level of project difficulty, and (c) the absence of significant metacognitive differences among the three groups of engineering students.

**Keywords:** metacognition; engineering design; cognitive self-appraisal; cognitive self-management



Engineering identity has been linked to both educational and professional persistence, but little has been reported on the views of professionals. The purpose of this study was to understand the relationship between engineering identity for students and professionals and how self-identification as an engineer changes over time and with certain key experiences. We surveyed a cross-section of undergraduate engineering students and alumni, within 10 years of receiving their undergraduate engineering degree, from the same institution during the spring of 2009. The survey yielded over 700 student responses and over 500 responses from alumni, and the differences in terms of who self-identifies as an engineer and what factors are viewed as most critical to engineering are reported. It was found that for both students and alumni work experiences are critical to self-identification but that gender was significant only for students. Finally, alumni were almost universally more selective in defining what factors (behaviors, experiences, etc.) are necessary to be considered an engineer. The one notable difference was in establishing relationships with fellow engineers in which a much higher percentage of alumni than students recognized it as necessary to be considered an engineer.

**Keywords:** engineering identity, professional persistence, educational persistence, gender



Engineering student's self-efficacy beliefs are strongly tied to their successful navigation of the engineering curriculum. Mathematics self-efficacy has been shown to be especially important to engineering student retention during the critical first two years of the curriculum. The purpose of this study is to investigate the changes in students' mathematics self-efficacy over the course of a

freshman engineering mathematics course and examine the reasons that these changes occurred, using a mixed methods research approach. As a group, students' belief that they could solve mathematics problems (problem mathematics self-efficacy) improved, but their belief that they could be successful in future mathematics courses (courses mathematics self-efficacy) did not. Following individual analysis, differential factors for groups of students who increased, decreased, or remained the same in each construct are described. Educators can use results to incorporate efficacy-developing aspects of their mathematics courses.

**Keywords:** self-efficacy; mathematics self-efficacy; engineering retention



Lifelong Learning (LLL) is critical for engaged citizens in the modern knowledge economy. The development of such generic or key competencies should be integrated throughout curricula, along with specific competencies in the disciplines such as engineering. This is a common educational goal in higher education in the USA and in Europe inside the Bologna Process. To enhance the capability of students to articulate their lifelong learning competencies, we developed a 'Lifelong Learning Competencies for Engineers' program for senior engineering students. This was presented as a workshop in a senior design course at the University of San Diego. The workshop includes presentations on lifelong learning competencies and specific recommendations for engineers, as well as an active learning exercise that helps students demonstrate their lifelong learning competence developed throughout their undergraduate career. Our mixed-methods evaluation reveals that the students improve their awareness of the importance of LLL at an important time in their lives as they finish their undergraduate academic career and move to the global labor market. Since lifelong learning spans disciplinary and national boundaries, this program could be adopted by other engineer educators and adapted by educators from a variety of fields.

**Keywords:** lifelong learning; key competencies, engineering education; professional development



As many recent reports and accreditation guidelines acknowledge, engineers are increasingly expected to work effectively across countries and cultures. This trend has helped establish and legitimate a mandate for providing more engineering students with educational experiences that enhance their global competency. However, there remain questions about what global competency means, and how it might develop and be assessed. This study addresses these themes by first arguing that cross-cultural competence is a key facet of global competency for engineers. It then presents an empirical study of US engineering students (n=147), using the Miville-Guzman Universality-Diversity Scale—Short form (MGUDS-S) to determine their openness to and appreciation of cultural diversity. An analysis of the dataset reveals significantly higher levels of cross-cultural competence among three groups of students opting into global engineering programs as compared to a baseline group of first-year students. Additionally, a pre/post-experience study focused on one of the global groups (n=55) indicates that an immersive research experience abroad significantly enhanced the cross-cultural competence of participating students. Also reported are variations in results based on factors such as gender and prior experience living abroad. The paper concludes by discussing some practical implications of our findings and opportunities for further research.

**Keywords:** assessment; cross-cultural competence; global competency; global engineering education; IREE; MGUDS-S; UDO; Universal-Diverse Orientation



The 'flattening of the world', using Thomas Friedman's phraseology, is driving corporations to increasingly use collaborative engineering processes and global teams to operate on a global scale. Globalization of the traditional university engineering curriculum is necessary to help students prepare to work in a global environment. More research is needed to identify, aggregate, and validate a comprehensive set of global competencies. The purpose of this research was to identify and validate a comprehensive set of global competencies for engineering students. A review of the literature was first conducted from which numerous global competencies were identified. From this list of competencies, a set of global competencies with an associated conceptual model was developed to group the competencies by contextual topics. Two surveys were then developed and distributed separately to academic and industry professionals to obtain a critique of the importance and comprehensiveness of the global competencies that were identified. From this research a comprehensive set of 23 global competencies was identified and arranged within five broad categories. The 23 competencies were validated by two professional groups who rated each of the competencies based on their importance. Not all of the competencies were considered to have equal importance, but each was considered to be at least somewhat important; preference was typically placed on dispositional-based global competencies. Academic and industry experts largely confirmed that it was important for engineering students to develop these global competencies.

**Keywords:** global; intercultural; cross-cultural; competence; engineering education; global engineering



The rising globalization trends of international competition and the changing societal, professional, and global landscapes for engineering graduates, call for action towards integrated learning strategies to prepare engineers for the future. This paper describes a global service–learning experience, the Global Design Team (GDT), which provides students with high-impact, multidisciplinary, collaborative experience. The global design experience is an intense international cultural exchange woven into service–learning development projects that address engineering grand challenges. This experience strives for positive, sustainable interaction with stakeholder communities through the application of technical skills and competencies of students to specific challenges within the partner communities. The research question addresses whether GDT is an experience effective at positively impacting the global competence of engineering students. The paper presents the GDT model and assessment results of two experiences in Kenya and Palestine. Students participating in GDTs are asked to participate in a pre/post course assessment that monitors the efficacy of the program in meeting a set of global competency outcomes, and community partners are asked to provide feedback on their relationship with the team. Results indicate that the GDT offers engineering students an experience effective at positively impacting global competence, with the potential to be expanded to institutions both nationally and globally. Furthermore, the international partners survey indicates that the GDT is an important service of value to the local community. The paper presents detailed survey and assessment results of what global attributes are impacted by this experience and ways to improve it. The paper shows that the GDT is a unique curricular experience towards changing the mindset of engineers from designing for an industrial-type client, to designing with a community.

**Keywords:** service-learning; global competency; multi-disciplinary teams; undergraduate design



The language used in engineering course materials may be a barrier to accurate assessment because students perceive the meanings of words differently. Universal Design in Education (UDE) has emerged as a strategy for making course material more accessible, but remains largely untested in this area. This study investigates whether students can accurately self-assess their understanding of vocabulary, i.e. if this is a 'visible' or 'invisible' deficit from the student's point of view, using a limited sample of ten words found in engineering exams. This is a preliminary investigation toward testing the efficacy of a UDE-based mitigation strategy, and it finds that students often inaccurately self-assess their understanding of language used in engineering examinations.

**Keywords:** language; accessibility; learner-centered

The slide rule is an important part of the heritage of the engineering discipline, but it was ultimately replaced as the new technology of calculators overtook it. Since this scenario is potentially repeating itself now with the introduction of remote laboratory classes in engineering, it is useful to compare the current situation of hands-on versus remote laboratories with the case history of slide rule replacement by calculators. Hands-on laboratories form a core part of the education of the current generation of engineers; this paper explores whether it is possible for remote laboratories to replace them. Remote laboratories are laboratories where students conduct experiments on real, physical equipment, but the students are not physically co-located with the equipment. The key factor is the fungibility of the learning outcomes that laboratories provide—whether the remote experience can achieve all or the most important of the things that the in-person-experience can. The slide rule became obsolete because new technology could achieve the most important of its outcomes, but quicker, easier and cheaper. An analysis of remote laboratories shows that many learning outcomes are able to be achieved more easily and more cheaply in the remote mode, and additional learning outcomes are also possible, with only a small number of non-fungible outcomes preventing remote laboratories replacing the face-to-face experience.

**Keywords:** remote laboratory; learning outcomes; fungible; slide rule



Engineering degree students sometimes feel that programming courses are not particularly relevant to their main subject and consequently are unmotivated and underperform. In view of this fact therefore, we have realized that in order to motivate them, programming practices must be related to other areas of their degree, in accordance with some principles of the EHEA (European Higher Education Area) process currently being implanted in European universities. This paper presents the work done over a ten year period in which we have tried to motivate the participation of the students studying Telecommunications Engineering in the University of Malaga during their studies. Conceptual maps produced as the result of a coordinated process between several professors in the different areas of the syllabus were used to design the practices and as a result the student success rate has improved while absenteeism has dropped.

**Keywords:** student motivations; programming courses; European Higher Education Area; conceptual maps for curricula



While engineering approximations are at the heart of engineering education and practice, students are rarely equipped with quantitative estimates of the errors associated with such approximations. Typically the curriculum includes only a qualitative discussion of the character of the errors involved and the assumptions made in using the studied approximate formulas or equations. Yet, as an engineer, the graduate student would often have to make decisions that depend on the level of accuracy of these approximations, e.g., a decision on the necessity to perform a costly computational analysis vs. relying on a standard approximate formula. The goal of this paper is to point to the need for in-class discussion on quantitative error estimates, as part of the engineering curriculum. As a case in point, the torsion of elastic rods with thin-walled cross sections is considered. Quantitative error estimates are provided for the standard formulas for the torsional stress and rigidity. A preliminary investigation is performed, involving 3rd-year students at the Department of Aerospace Engineering, Technion, at the end of a Structural Analysis course. This preliminary study shows that without having been exposed in class to quantitative error estimates, intuition leads most of the students to making the wrong practical decisions in some situations, which might have a negative impact on their future work as engineers. This study thus points to the educational benefit in teaching the subject of quantitative error estimates for engineering approximations during undergraduate studies. In the case of a 3rd year Structural Analysis course, the material associated with the subject would require about half an hour of frontal teaching, but can also be offered to the students as an enrichment in writing for self-study.

**Keywords:** engineering education; error estimates; solid mechanics; structural mechanics; torsion



Although several researchers have studied the use of educational software in electrical machine courses, the lack of educational software to design wire winding of electrical machines is felt. It has been continually the concern to create an educational software package to help both the students and lecturers to design wire winding diagrams easily because the process of design by hand is difficult.This paper introduces an interactive software package created by the authors, named WWEM (Wire Winding of Electrical Machines), to assist students to grasp various wire winding models and their design principles. In addition, it tries to facilitate the process of designing diagrams in order to improve students' learning and at the same time lecturers' teaching. WWEM consists of various wire winding models of electrical machines, Particle Swarm Optimization (PSO)—a swarm intelligence technique—and MATLAB programming. WWEM gives optimal design of wire winding using PSO. The present study was performed on undergraduate students attending the course 'wire winding of electrical machines'. A statistical hypothesis test on student marks in the final exam showed that the majority of the students who had employed WWEM got the highest marks; they had became more competent in the area of wire winding. Based on this, the authors suggest that the use of WWEM will help lecturers to identify the students' level of understanding so that they can explain better the concepts of wire winding. WWEM is capable of being included in MATLAB Power System Toolbox (SimPowerSystems) as one the characteristics of electrical machines and used on the Web, as well.

**Keywords:** educational software package; electrical machines; MATLAB; PSO; wire winding; WWEM



This paper explains how to set up a practical experiment to teach the mechanics of flight by means of a modular aeroplane, i.e., an in-field configurable aeroplane that can be designed and assembled by the student for specific mission requirements. The concept comprises a catalogue of modules including pure and aileron-mounted lifting surfaces, propulsion, vertical surfaces, longitudinal extensors, landing supports and other smart modules, all with common structural and electrical interfaces. A software tool is able to quickly assess, using a vortex lattice method, the feasibility of flight and the proper position of centre of mass. Once the aeroplane is built, the parameters and flight path can be uploaded onboard and tests can be performed. Real time and playback monitoring allow the student to check if a selected configuration performs appropriately with respect to the requirements. In addition, a set of simple practical exercises and the expected results are proposed in the paper.

**Keywords:** aeronautics education; mechanics of flight education; modular aeroplane; unmanned aeroplane; vortex lattice; outdoors experiment; practical education