

The International Journal of Engineering Education

Contents

Section I

Special Issue

Open Source & Collaborative Project Based Learning in Engineering Education

Guest Editors

Andrés Díaz Lantada—Universidad Politécnica de Madrid, Spain
Carmelo De Maria—Università di Pisa, Italy

Ahmad Ibrahim	1277	Editorial
Andrés Díaz Lantada and Carmelo De Maria	1278	Guest Editorial
Andrés Díaz Lantada and Carmelo de Maria	1279–1289	Towards Open-Source and Collaborative Project-Based Learning in Engineering Education: Situation, Resources and Challenges

Several strategies have been proposed for the promotion of successful and sustainable project-based learning (PBL) activities, whose benefits for higher education institutions include: improvements in student learning outcome, given the more holistic learning environments that provide the complex implications of the engineering practice; the engagement of the community of professors, which get involved in a shared dreams environment and increase their mutual communication; the promotion of technological and research vocations and the enhanced interconnections between academia and industry derived from PBL experiences devoted to solving real societal and entrepreneurial challenges.

The incorporation of collaborative creation or collaborative design methods and the use of open-source resources may provide additional benefits to this teaching-learning methodology, by helping to make these experiences more formative, more easily replicable, sustainable and cost-effective.

In this study we concentrate on the promotion of active learning experiences linked to collaborative engineering and supported by open-source tools and resources. To this end, we analyze available resources for supporting educators in planning and students in living open-source collaborative PBL (OSC-PBL) experiences. Then, a case of study linked to OSC-PBL in the biomedical engineering field is presented and examined. Finally, lessons learned and current challenges for the future success of these teaching-learning experiences are discussed.

Keywords: project-based learning, service learning, open-source engineering education, collaborative design

Juan M. Munoz-Guijosa, Andrés Díaz Lantada, Javier Echávarri and Enrique Chacón	1290–1305	Using Smartphones Physical Interfaces in Engineering Education: Experiences in Promoting Student Motivation and Learning
--	-----------	--

Smartphones are already taking part of the everyday life of more than two and a half billion people. University students are one of the population groups in which smartphone penetration is more intense. Applications for activities organization, voting, translation, information sharing, flashcarding, etc. are already of general use. However, despite the considerable big number of available data acquisition and analysis applications, few learning activities take advantage of the smartphone physical interfacing capabilities (accelerometers, gyroscopes, magnetometer, microphone, camera, flashlight, loudspeaker), which, due to the present computing power of smartphones, are excellent. This leads to infer that smartphones could be a relevant tool for enhancing the teaching-learning process in technical studies. Students attending to engineering careers are an especially adequate target for smartphone aided teaching due to their training in the use of computers and other electronic equipment and their strong previous knowledge in fields as programming or quantitative data management. In this work, the data acquisition capability of smartphones is studied, different teaching-learning activities based on this capability are proposed, and the impact of the introduction of three representative smartphone-based learning activities, as balancing of shafts, evaluation of stick-slip instabilities or machine acoustic power measurement, is analyzed.

Keywords: computer aided teaching; data acquisition; data analysis; smartphones

Pilar Pazos, Stacie I. Ringleb, Jennifer Kidd and Rachel Jones	1306–1315	Scaffolding Project-Based Learning in an Engineering and Education Partnership using Open-Access Technology
---	-----------	---

This paper describes the use of a freely-accessible open-source platform based on Google Apps for Education that combines Google Sites, Google Docs, Google Drive, Google Hangouts and script language in a custom-based interface that supports collaborative service-learning projects for teams of Engineering and Education students. The approach discussed in this paper was successful in promoting collaboration among students from two different disciplines working remotely. The analysis suggests that balanced participation in the team, presence of shared goals and clear roles that emphasized individual and collective responsibilities were key to a successful interdisciplinary project experience. While many students still reported struggling with normal teamwork challenges, like finding common meeting times, others were pleased with the dynamics of their team and the opportunity to learn from one another. While SCOL, the open-source collaboration tool, did not significantly predict team satisfaction, the instructors found it very valuable for structuring project tasks, monitoring student progress, and providing timely feedback. The tool was seen as critical in supporting cross-disciplinary course collaboration for which students had limited access to face-to-face interaction. Faculty emphasized the importance of training students to use the asynchronous communication and collaboration tools (e.g., Google Docs and Google Hangouts) to maximize the benefits for students. Training will be included in future implementations of SCOL to ensure a more effective use of the platform.

Keywords: project-based learning; interdisciplinary teams; engineering education; collaboration technology

William Villegas-Ch, Xavier Palacios-Pacheco, Diego Buenaño-Fernández and Sergio Luján-Mora 1316–1325 Comprehensive Learning System Based on the Analysis of Data and the Recommendation of Activities in a Distance Education Environment

Traditional teaching, based on techniques in which students develop a passive function, has proven to be an inefficient method in the engineering learning process. Universities have been forced to improve their teaching methods and have found a partial solution in open source platforms; these platforms have allowed a greater collaboration between institutions that improve the contribution of technology to education. There are cases of collaboration between universities where their sole objective is to promote student learning and the automation of educational processes. The massification of this type of technological tools allows the use of systems and platforms commonly used in the business world. This adoption of open source tools has proven to be very effective in educational environments and has offered several benefits such as the reduction of costs and the constant updating of information systems. One of the frequent cases in which there are collaborative projects based on learning is the analysis of educational data that seek to detect students' deficiencies and to take actions before they abandon their studies. In this work, we propose the design of an integral learning system in which business intelligence, expert systems, learning management systems and different learning techniques converge. This integration seeks to create a system capable of recommending different activities that focus on the needs of students.

Keywords: open source; expert system; engineering education; project based learning; data mining

Ayhan Istanbulu and Mustafa Tasci 1326–1335 Open Source Hardware—Arduino: Case Study on Mechanical Engineering Students Design Project

This paper examines the effectiveness of using Arduino, which is open source hardware, as a learning instrument to teach how to apply software programs into mechanical projects by encouraging team working and utilizing project based learning (PBL) approach for mechanical engineering education. The compulsory Engineering Design Course in the curriculum of the Department of Mechanical Engineering was selected because of its strong relationship with the sector and real-world projects while lending itself to addressing to see the major consequences of using PBL and open source hardware. Fifteen third-year mechanical engineering students took the lecture. A survey was conducted to see learners' attitude toward using this technique and to evaluate the effect of using open source hardware in engineering education. The lecturers have focused on the usefulness and ease of using Arduino platform to develop real-life projects for the learners. The results will provide useful data to future research on using open source lecture materials in engineering education.

Keywords: open source hardware; project based learning; Arduino and mechanical engineering

Manuel Vargas, Miguel Alfaro, Guillermo Fuertes, Gustavo Gatica, Sebastian Gutierrez, Soledad Vargas, Leonardo Banguera and Claudia Duran 1336–1342 CDIO Project Approach to Design Polynesian Canoes by First-Year Engineering Students

A design of a nautical project using the active learning method based on projects, was developed and implemented in two universities in Chile. The main objective of this research is the search of learning methodologies stimulators of the cooperative work of students in complex projects. The educational project uses the concurrent engineering supported by an informatics platform and the following design technics: Computational Fluid Dynamics (CFD), Computer-aided Manufacturing (CAM), Finite Element Method (FEM) and Computer-aided Design (CAD). The teams are grouped by capabilities and technical interests, working in the different stages of development of the project of a nautical team for an international competition. The programming of the activities carried out by the students include are the 3D digital design, the ergonomic studies, the computational simulations of fluids, the resistance analysis of materials, the 3D prototype and the computer-aided manufacturing. Finally, this research compares the conceive-design-implement-operate (CDIO) methodology with the methodology of lecture classes and presents the learning results and the challenges of the experience.

Keywords: active learning method; computer-aided design; computational fluid dynamics; CDIO

Kausar Jahan, Cheryl Bodnar, Stephanie Farrell, Ying Tang, Iman Noshadi, C. S. Slater and Demond S. Miller 1343–1352 Improving Students' Learning Behaviors Through Hands-On Algae Based Project

Algae were used as a special topic area for a first-year engineering project that was collaboratively taught through instructional pairing. The selection of "algae" was intentional as it is ubiquitous and it has been used by many civilizations for nutrition, healing, and in aquaculture. The current challenging research on algae ranges from biofuels, innovative materials, electricity to much more. As such, algae can be used for teaching a variety of core engineering concepts such as materials, energy, fluid mechanics, thermodynamics, water and wastewater treatment, nutrition, and green engineering. The "algae" theme can also be easily extended to integrate concepts from humanities such as global engineering challenges, ethics, gender/racial biases, and public policy. The overarching goal of the algae project was to introduce students to project based learning using a live organism and to expose students to engineering fundamentals and core concepts from the humanities. The project was taught over the course of four weeks of a semester with a group of 69 first year engineering students. Hands on activities along with a team project were an integral part of the course. Students were assigned to teams and then given the role of investigating the potential for algae to be used to grow the economy of a country of their choice. Over the course of the project, students conducted hands-on experiments focused on cell culture, harvesting, gas transfer, and other algae applications. The team project allowed them to learn about governance, politics, policy, economy, and social issues about their country. Students' adaptive learning practices and perceived confidence of learning were assessed through surveys and focus groups. Students demonstrated increases in their learning goal orientation, task value and perceived confidence in learning with some statistically significant changes as observed in their self-efficacy and self-regulated learning. Focus group results further supported how this project was able to provide a venue for students to make connections with their selected career path and build perseverance when facing difficult problems. Although the sample size is small, the results show positive trends for the use of an algae based collaboratively taught project to improve student's adaptive learning and perceived confidence in learning.

Keywords: project-based learning; humanities; global challenges; algae

Emad Habib, Matthew Deshotel, Guolin Lai and Robert Miller 1353–1365 Student Perceptions of an Active Learning Module to Enhance Data and Modeling Skills in Undergraduate Water Resources Engineering Education

This article describes the design, development, and evaluation of an undergraduate learning module that builds students' skills on how data analysis and numerical modeling can be used to analyze and design water resources engineering projects. The module follows a project-based approach by using a hydrologic restoration project in a coastal basin in south Louisiana, USA. The module has two main phases, a feasibility analysis phase and a hydraulic design phase, and follows an active learning approach where students perform a set of quantitative learning activities that involve extensive data and modeling analyses. The module is designed using open resources, including online datasets, hydraulic simulation models and geographical information system software that are typically used by the engineering industry and research communities. Upon completing the module, students develop skills that involve model formulation, parameter calibration, sensitivity analysis, and the use of data and models to assess and design a hydrologic a proposed hydrologic engineering project. Guided by design-based research framework, the implementation and evaluation of the module focused primarily on assessing students' perceptions of the module usability and its design attributes, their perceived contribution of the module to their learning, and their overall receptiveness of the module and how it impacts their

interest in the subject and future careers. Following an improvement-focused evaluation approach, design attributes that were found most critical to students included the use of user-support resources and self-checking mechanisms. These aspects were identified as key features that facilitate students' self-learning and independent completion of tasks, while still enriching their learning experiences when using data and modeling-rich applications. Evaluation data showed that the following attributes contributed the most to students' learning and potential value for future careers: application of modern engineering data analysis; use of real-world hydrologic datasets; and appreciation of uncertainties and challenges imposed by data scarcity. The evaluation results were used to formulate a set of guiding principles on how to design effective and conducive undergraduate learning experiences that adopt technology-enhanced and data and modeling-based strategies, on how to enhance users' experiences with free and open-source engineering analysis tools, and on how to strike a pedagogical balance between module complexity, student engagement, and flexibility to fit within existing curricula limitations.

Keywords: water resources engineering education; active-learning; numerical modeling; data analysis; project-based; improvement-focused evaluation; design-based research; open-source tools

Divna Krpan, Saša Mladenović and Goran Zaharija 1366–1377 The Framework for Project Based Learning of Object-Oriented Programming

Learning programming requires various skills and knowledge that novice programmers are expected to obtain in a limited time frame during introductory programming courses. Students are often introduced to programming for the first time at the university and overwhelmed with different programming languages and paradigms. Teachers are changing strategies and educational researchers are analyzing the data to suggest different paths. However, long-term studies in learning and teaching programming are not that common. In this research we present the analysis of using specially designed open source framework for teaching object-oriented programming during five years.

Keywords: problem-based learning; object-oriented programming; didactic reduction; game-based learning

Gordon Hoople, Austin Choi-Fitzpatrick and Elizabeth Reddy 1378–1391 Drones for Good: Interdisciplinary Project-Based Learning Between Engineering and Peace Studies

Engineering practice is inherently interdisciplinary. Current curricular structures, however, provide engineering students with few opportunities to work across disciplinary boundaries. In this article we report on a project-based course where students from a School of Engineering and a School of Peace Studies were brought together to design a drone that would have a positive impact on society. The course learning objectives focused on students' abilities in relationship to broader contextual issues (process), a bounded technical challenge and its social implications (project), and their role in the process (reflection). A key goal for the course was to help students recognize how their disciplinary identity shapes the way they approach problems and to recognize the value of perspectives from other disciplines. We present an analysis of both qualitative and quantitative data to explore whether the course met these objectives and to reflect on the opportunities and challenges such a class provided for our students. We determine that we have developed the basis of a promising model for engaging students from multiple schools and background and we conclude by proposing future scholarship.

Keywords: multidisciplinary design; interdisciplinary; communication skills; drones; peace studies; robotics; UAV; UAS

O. Picton, R. Losada, I. Fernández De Bustos and E. Rojí 1392–1401 Glued-Wood Structure Development Contests for Project Based Learning in Engineering and Architecture Degrees

The contests involving the development of glued wood structures represent a motivating challenge for the students. These activities are rightfully included in the field of active learning or Project Based Learning. The advantages of these kind of contests is its low cost, especially when compared to other similar contests such as Formula SAE or others. This makes these competitions affordable to all students. Furthermore, these competitions are more civil engineering oriented. Surprisingly enough, in most of the competitions the academic performance has a lot of room for improvement. This is mainly due to the fact that they were considered more as a promotional event than a useful teaching tool, especially in the first editions. In the work presented in this paper, the technical aspects of these contests have been studied in order to improve, as much as possible, the learning aspect of those events. In order to do so, a review of the current state of the art in those contests is performed. After that, some technical considerations on the possibilities that those contests allow are developed. This is done while keeping, as much as possible, the reduced costs of these events. After that, the recommendations have been put into practice in a real scenery and some conclusions are exposed. This has been made via a pilot experiment where a student has been asked to analyze the glued-wood structure that it was developed by him in a contest.

Keywords: active learning; structural analysis; bridge models; glued wood; educational model contests

Orna Muller, Vered Dangur and Orit Braun Benyamin 1402–1414 Developing Devices for People with Disabilities: Challenges and Gains of Project-Based Service Learning

The development of a product according to specific requirements is the engineers' core mission. Therefore, engineering programs need to equip their graduates with the tools to deal with the entire cycle of product development. Project-Based Service Learning (PBSL) is a hands-on pedagogical approach that involves the development of a product for the benefit of society. PBSL provides students with opportunities to design and develop innovative solutions for real clients with real needs.

The study focuses on the perceptions of 13 mechanical engineering graduates who participated in a one-semester Rehabilitation Biomechanics course that includes development of tailor-made and low-cost assistive devices for people with special needs. The study aims to evaluate the long-term impact of PBSL on graduates, after several years of employment in industry. The course is a part of an ORT Braude College of Engineering flagship project: "Engineers on Behalf of People with Disabilities". The study uses the Grounded Theory qualitative research methodology that allows revealing ideas that could not be foreseen.

Interviews with the graduates exposed the challenges they experienced during the course as well as the gains. They have developed an awareness of the roles of engineering solutions in assisting people with special needs. The direct and challenging interaction with disabled customers changed their attitudes towards people with special needs, and developed in them an empathetic Client-Centered Design approach. The PBSL experience influenced graduates' interests, careers, and personal development, and the skills they brought to their workplaces.

Research shows how PBSL may bridge the gap between theory and practice, looking at the community as a legitimate partner in the development of innovations. An outcome of the flagship project is the founding of an online "Knowledge Base for Daily Life Activities (DLA) Solutions" resource, which is available to the public.

Keywords: project-based service learning; engineering education; people with disabilities; rehabilitation biomechanics

Mandy Mclean, Jasmine Mcbeath, Tyler Susko, Danielle Harlow and Julie Bianchini 1415–1424 University-Elementary School Partnerships: Analyzing the Impact of a Service-Learning Freshman Engineering Course on Students' Engineering Values and Competence Beliefs

There is a growing demand in the US for more engineers, yet attrition rates from university engineering programs are high and diversity in engineering is low. Few resources have been dedicated to the improvement of freshman engineering courses even though freshman students have the highest rates of attrition. Through a synthesis of the literature on inclusive instructional strategies and participant structures in educational settings, we developed, implemented, and researched a freshman mechanical engineering design course that incorporated elements of project-based learning, collaboration, service-learning, and customer-oriented design through a partnership with a local elementary school. Our research was grounded in the value and competence belief constructs defined by expectancy-value theory. Engineering values include enjoying engineering tasks, viewing engineering as

useful, and identifying as an engineer and engineering competence beliefs encompass beliefs in one's engineering abilities in the present, as well expectancies for success in the future. Rich qualitative data collected from 72 undergraduate participants suggested that this course was both highly valued and helpful for increasing engineering competence beliefs. Further, these positive impacts were consistent across gender. From our results, we provide recommendations for strategies to help grow and diversify engineering.

Keywords: expectancy-value theory; freshman engineering education; project-based learning; collaboration; service-learning, customer-oriented design

Brenda Vilas Boas, Marcus Dias, Pedro Batista, Aurenice Oliveira and Aldebaro Klautau 1425–1435 CELCOM Project: Engineering Practice via Community Networks in Amazon

Concurrent technological, political, and economic events have led to increasing globalization of the world economy. Industry has responded to this transformation by redefining business strategies and new expectations for the set of skills required from college graduates, especially in science, technology, engineering and mathematics (STEM) areas. As a new generation of engineering students get closer to graduate, they are challenged with important issues at local, regional, and global levels. The access to information and communication technologies (ICTs) as a tool for education, economic development, and social well-being is one of these important issues. In this paper, we share a Problem Based Learning (PBL) project focused on ICTs to teach telecommunication technologies to engineering students. This project also has the goal to train and educate students in Humanitarian Engineering to improve the well-being of communities in the Amazon region of Brazil. The results demonstrate that students participating in this PBL project develop a more solid technical background, research and design skills, critical soft skills, better perception of the telecommunication industry and a better understanding of the standardization bodies.

Keywords: ICT4D; Problem Based Learning; wireless communication; Software Defined Radio; community networks

Daniel López-Fernández, Laura Raya, Fernando Ortega and José Jesús García 1436–1445 Project Based Learning Meets Service Learning on Software Development Education

This contribution presents several case studies performed using Project Based Learning and Project Based Service Learning methodologies. The case studies have been carried out for two years in a Software Engineering degree. Qualitative methods like surveys, observations and interviews have been used to investigate both methodologies. The results obtained lead to useful guidelines for those Engineering teachers who intend to use these methodologies in a productive and enriching way. The data indicate that motivation, soft skills and technical abilities of the students are improved using these methodologies. Critical issues like project selection, communication with clients, session performing, conflicts prevention and evaluation methods are addressed. Recommendations to implement successfully these methodologies are stated.

Keywords: active methods; project based learning; service learning; project based service learning; software engineering; software development

M. Royo, M. Carlos, R. Izquierdo and L. Cabedo 1446–1455 Industrial Design and Social Prospect: A Service-Learning Experience for Second Course Undergraduates

How is social responsibility being applied at the University and what are the steps and experiences carried out in this field? This article shows a service-learning experience carried out in the Industrial Design and Product Development Engineering Degree at Jaume I University (Castellón de la Plana) during the academic year 2017/18. In this experience, two subjects in the second year of the degree were involved: Conceptual Design (in the first semester) and Materials II (during the second one). Moreover, students' final works, as well as professors' and students' assessments, are collected and presented. Results show that although the experience is complex and requires great abilities for coordination between professors, these experiences help boosting the implementation and development of complex projects, committed to promoters, which achieve positive assessments and results.

Keywords: service-learning experience; university; social responsibility; product design

Gilberto Duarte Cuzzuol, Lilian Barros Pereira Campos, Diana Mesquita and Rui M. Lima 1456–1465 Collaborative PBL to Teach Calculus to Engineering Students: The Important Role of Collaborative Professors

Teaching Calculus can be one of the most challenging practices in the engineering context for several reasons. It is taught at the beginning of engineering courses in a critical phase of student transition between high school and university. And most of the time, students are not able to understand the meaning of some contents in relation to Engineering. In the engineering education context, the disciplines of Calculus are responsible for high failure rates and students' dropout. Besides that, lectures are predominantly used, with rigid contents centered on the blackboard and in the book. Therefore, students have low interaction with teachers. Besides, students have difficulty building their own knowledge and to understand the importance of mathematical methods and procedures. However, this paper shows a collaborative project-based learning (CPBL) experience to teach Calculus to engineering students with an important support of capstone courses teachers as collaborative professors. Students were asked to choose a phenomenon of their Engineering area of knowledge and explain why and how it needs integrals and derivatives to be explained. 127 students from six engineering courses were involved in the experiment. The students were organized in teams and tutored by capstone courses faculty. These professors were called collaborative professors. This paper aims to describe the collaborative professors' interactions with the teams and analyze the outcomes in terms of the perception of learning and development of transversal competences. The evaluation was based on content analysis of the reports delivered by the students. 100% of the groups evaluated the experience as positive. The students used adjectives such as "excellent", "extraordinary" to characterize the experience. In addition, students reported the following learning outcomes: knowledge and understanding; analysis; problem-solving; creativity/originality; communication and presentation; evaluation; planning and organization; interactive and group competences. Some groups reported that, in this project, they used laboratories and created prototypes that they will keep on researching and developing to take these ideas to the market. Yet, in this experience, the failure rate of this discipline that previously was 95% dropped to 5%.

Keywords: active learning; project-based learning; calculus for engineering; engineering education

Eri Ota, Rie Murakami and Proadpran Punyabukkana 1466–1479 Comparative Analysis on Effect of Multicultural Project-Based Learning Between Universities in Japan and Thailand

The purpose of this paper is to determine trend and characteristics of engineering students' motivation and learning outcome of multicultural project-based learning (PBL) between two universities in Japan and Thailand. Tokyo Institute of Technology in Japan and Chulalongkorn University in Thailand have been conducting multicultural PBL titled "Global Awareness for Technology Implementation in the Solving of Global Issues" since 2015. The program is composed of on-line group work in remote setting, and both-ways visits to and from Japan and Thailand. This paper discusses in detail trend and characteristics of motivation and learning outcomes of multicultural PBL for students from Tokyo Institute of Technology and Chulalongkorn University. In so doing, this paper summarizes (1) process of Multicultural PBL, (2) functions and roles of on-line tools for communication for program implementation, and (3) result of comparative analysis. For comparative analysis, following methods were utilized; (1) pre and post survey using Likert scale, (2) content analysis using personal essays, and (3) participants observation. Based on the multicultural PBL's objectives, five indicator-categories namely (1) global awareness, (2) multicultural understanding, (3) multicultural teamwork, (4) critical thinking, and (5) technology implementation are set. Several finding which are common to students from both universities for both years were observed. First, it was found out that students had high interests on going

abroad before they join the program. Second, students are interested in advanced countries. Third, even before joining the multicultural PBL, students have realized the importance of respecting cultural differences. Forth, before the program, they are not yet prepared for finding solution for social issues, as wells as methods of technology localization/implementation. Fifth, after joining the multicultural PBL, students have increased understanding of cultural differences and knowledge on the topics related to two countries. Sixth, students kept high motivation to visit abroad and high interest on advanced countries from the beginning until the end of the multicultural PBL. By assessing the motivation and learning outcome of the students from two universities in Japan and Thailand, this paper also summarized the lessons learnt and key for the success in implementing multicultural PBL.

Keywords: multicultural project-based learning; on-line group work; mutual visits

Danielle Miquilim and Marcia Terra da Silva

1480–1492 The Teaching of Innovative Entrepreneur Engineers: Key Factors that Contribute to Teaching-Learning Processes and University Management

With the purpose of increasing undergraduation student admission, decreasing dropout rates, and improving the insertion of newly undergraduates in the market, an increasing number of engineering schools have been looking into implementing teaching models aimed at innovation and entrepreneurship. To these schools, collaborative projects, the use of social media, PBL and other teaching methodologies are common activities. However, these are not commonly practiced in traditional Brazilian HEIs. Therefore, the objective of this study was to identify the level of importance professionals directly involved in engineering teaching attribute to the main factors inherent to the implementation of an innovation and entrepreneurship-focused course. The applied method was the content analysis of interviews made with managers, coordinators, professors, and students from 4 of the major engineering schools from the city of São Paulo, Brazil. One of the main identified changes in the teaching-learning processes of these HEIs was the project-oriented teaching. However, the interviewees believe there is a critical factor involved in the implementation of this model of teaching, which is the significant change in the professors' mindset. The process of cultural change is being implemented in different ways and, from the professors' points of view, people management aspects overlap technology use as far as their importance is concerned.

Keywords: engineering education; teaching learning process; university management

Siva Chandrasekaran and Llewellyn Mann

1493–1502 Case Study of Facilitating Practice-Based Education in a Studio-Based Learning Environment

The practice-based education (PBE) is a practice-based project centric learning experience. Learning through projects in teams and engaging learners through real-world problems in partnership with industry is not new. What is new in the implementation of the PBE is placing learners in a context that is modelled as an engineering practice. This paper is focused on analysing the experiences of teamwork dynamics within a group of associates working for an industry project in a studio-based learning environment. An online survey is given to the associates (students) at the end of sprint which is anonymous and voluntary to participate. The collected data are analysed to explore associates experiences on collaboration, interaction, teamwork, and communication through professional practice in a studio-based learning approach.

Keywords: studio-based environment; practice-based education; facilitation; teamwork

Section II

Contributions in: Global Competence, Internship, Flipped Classroom, Low Self-esteem, Industry 4.0, CDIO, Motivation, MOOC, Assessment, and Critical Thinking, Distributed Practice, Engineering Mathematics

Scott C. Streiner and Mary Besterfield-Sacre

1503–1517 Measuring the Relative Impact of International Experiences on Engineering Students: A Benchmarking Analysis

Engineering educators and higher education leadership believe those students who are able to work effectively with colleagues across national, cultural, and ethnic boundaries will be more prepared and successful post-graduation. Research has shown that international experiences have a positive impact on students' global perspectives. Unfortunately, engineering students' participation in said experiences is relatively low (historically), due to a variety of reasons such as lack of preparation, highly sequenced curricula, and lack of integration. Thus, engineering schools who are investing in internationalizing their programs need to determine whether these investments are producing their intended results and what experiences have the greatest impact. This study explores how engineering students utilize international experiences while in college and which experience types are most effective relative to global perspective development. Results from this study suggest that internships, co-ops, and technical research conducted abroad provide the largest impact to improving global perspectives while also being the least frequent type of experience. Further, the largest gains in global perspectives occurs after one international experience or by participating in a variety of experience types. This study supports a means by which global perspectives should be developed in engineering students—i.e., improving the global perspectives of an increasing diverse student population to what is empirically possible given the opportunities available to them, mediated by their upbringing and background. As institutions continue to invest time and resources into education abroad experiences, it is important to determine how students can get the most out of the available international opportunities, especially as students are presented with more and more options as to the types of activities and educational practices they can engage in during college.

Keywords: global competence; international programs; student backgrounds; internships

Po-Wen Cheng, Po-Wen Liu, Chin-Chung Huang and Wen-Jye Shyr

1518–1525 The Effects of the Flipped Classroom on Technical High School Students with Low Self-Esteem

This study aimed to investigate the effectiveness of flipped classroom practical project-based teaching on the learning of technical high school students with low self-esteem. This study used experimental research methods conducted for a total of 8 hours over a 4-week period of practical project-based instruction as experienced by the subject of the study engineering student at a technical high school in Taiwan. Students in the experimental group were taught using the flipped classroom method, while students in the control group were instructed via traditional teaching methods. Statistical analysis of student grades was conducted before and after the experiment, resulting in the following findings: (1) The flipped classroom method contributed to improving student learning ability and learning effectiveness in practical project-based course. (2) The flipped classroom method contributed to improving the test scores of students with low self-esteem. After interviewing the students with low self-esteem and gathering their feedback, this study discovered that students found previewing course presentations and interacting with other students in small groups to be very helpful. The flipped classroom method notably increases the feasibility of implementing practical project-based course and the effectiveness of student learning.

Keywords: low self-esteem; technical high school; practical project-based course; flipped classroom

To solve the current problem concerning the education and skills gap of college students as well as to cultivate mold design talent in line with Industry 4.0 for the mold industry, this study established a mold design concurrent system program using the conceive–design–implement–operate (CDIO) teaching model and assessed the effectiveness of the model through program implementation. First, the development trends of the mold industry in Taiwan and the human resources strategy of the smart mold manufacturing industry of Industry 4.0 were investigated to explore the standard of engineering talent in the industry and create a competency indicator for mold design concurrent systems to serve as an essential reference for curriculum planning and the criteria for learning outcome assessments. Second, the scope covered by the mold industry in the product life cycle was used as the blueprint for developing the curriculum. Finally, the CDIO curriculum design principle was applied to the design of the integrated curriculum module. Experimental teaching was conducted in the Bachelor’s Program in Precision System Design at Feng Chia University in Taiwan for 18 weeks. A total of 54 sophomores participated in the experimental program and the product research and development project entitled “Design and transformation of older-adult-friendly living supplies” to experience the entire process of CDIO. The curriculum consisted of a total of seven courses and six teachers (including three industry experts) and offered 15 credits. Moreover, this study used the competency indicator scale in the pre- and post-tests to evaluate the effectiveness of the experimental teaching. At the end of the semester, a student program satisfaction survey was conducted to assess the effectiveness of the curriculum design and implementation. The results revealed that the students’ competency indicators exhibited significant progress in understanding the professional technology of molds, using CAX software, and understanding concurrent system engineering capabilities. Moreover, the students were highly satisfied with the program, and the item “The engineering practice of the integrated curriculum is helpful for my future academic progression and employment needs” received the highest level of satisfaction. This program was proven effective for cultivating excellent mold design talent for the industry, thereby bridging the mismatch between knowledge and application among university graduates and serving as a great example for higher-level engineering education reform.

Keywords: mold design program; CDIO; integrated curriculum; program module; Industry 4.0; concurrent system; engineering education

Mitchell Zielinski, Victoria West, Hillary E. Merzdorf, Kerrie A. Douglas and Peter Bermel 1540–1550 Motivation and Perceived Costs to Achievement in Advanced Engineering MOOCs: A Mixed Method Study of Advanced Engineering MOOC Learners’ Motivation and Perceived Barriers

Given recent, rapid changes in engineering workplaces, massive open online courses, or MOOCs are a promising option for educating the workforce with new knowledge and skills. However, few take full advantage of these resources, in part because professional learners can have many constraints limiting their ability to fully participate. Our research uses an explanatory mixed-methods design to examine differences in learners’ self-reported factors hindering their ability to succeed in a course, and their perceived outcomes of not finishing the course. We administered a pre-course survey in three advanced nanotechnology MOOCs to survey learners’ motivation from an Expectancy–Value–Cost framework, resulting in 806 responses. Learners responded to the short version of the EVC scale, as well as two open-ended questions regarding barriers to engagement and perceived outcomes of failure in the course. Using the cost subscale, we grouped learners into the highest and lowest cost quartiles. In parallel, we developed codes and themes for the qualitative items via open coding and used themes to compare high-cost and low-cost learners on areas which affect their potential success and effects of failure. Both groups cited barriers of work, time, and personal commitments, with high-cost learners reporting these factors more often. They generally listed few consequences of not being successful, but an equal number of high-cost and low-cost learners wanted to retake the course if they failed. Professionals balance motivational costs from many areas when participating in courses, and advanced professional MOOCs must be accommodating if learners are to persist.

Keywords: motivation; MOOCs; barriers

Adam R. Phillips and Colin Lambie 1551–1560 Assessing Civil Engineering Students Perceptions of Their Problem Solving Ability

The most widely utilized metric for judging academic achievement is grade point average (GPA). However, GPA is not always indicative of critical thinking and problem-solving ability, which are the universal traits required of engineers. This paper presents a new assessment tool for measuring an individual’s self-appraisal of their technical problem-solving ability and the initial validation of the tool using a pilot study involving 73 undergraduate Civil Engineering students and faculty. The new assessment tool is called the engineering modified problem-solving inventory (EM-PSI) and is an adaptation of a more general problem solving inventory that has been utilized throughout psychology and counseling research. This paper investigates three pertinent questions: (1) What relationship, if any, exists between undergraduate students and faculty and EM-PSI score, (2) What relationship, if any, exists between gender and EM-PSI score, and (3) What relationship, if any, exists between undergraduate students with or without parents who are engineers and EM-PSI score? Internal reliability assessment of the EM-PSI was evaluated using Cronbach’s alpha and determined that the modified survey was acceptably reliable. The results of a Wald ANOVA and post-hoc tests showed that there were significant differences in EM-PSI and subscale scores between undergraduate students and faculty members. Faculty self-appraisal of their problem-solving ability was higher than that of students. Additionally, two dimensions of problem-solving, approach-avoidance style and personal control, were identified to be most different between faculty and students. This paper demonstrates that the EM-PSI is a promising new assessment tool that may assist instructors in evaluating student problem-solving ability.

Keywords: problem solving inventory; critical thinking; engineering assessment

Ahmet Refah Torun 1561–1565 The Effect of Weekly Distributed Mathematics Homework and Quizzes on the Learning Performance of Engineering Students

Education should promote learning which goes beyond short-term memory and lasts for years. Many research results suggest that a repeated practice over time is necessary to achieve long-lasting and long-term learning. Engineering mathematics consists of the basic skills which every kind of engineer must master. Within the scope of this study, we developed a learning system for mathematics lectures of engineering students. Instead of evaluating the students with midterm and final examinations, we evaluated a group of 89 engineering students with weekly homework and quizzes and compared it with two control groups of 85 and 114 engineering students. Our hypothesis for this study is: Learning by doing with guidance and distributed practices leads to better learning results than just watching the lecturer explaining and solving exercises. The midterm and final examinations are analogous to massed practices which cannot penetrate into the field of long-term learning. The comparison with two control groups showed that the grades and long-term learning effects are significantly higher for the group with weekly homework and quizzes.

Keywords: engineering mathematics; distributed practice; spacing effect; anti-anxiety curriculum