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Ahmad Ibrahim

855 Editorial

Xuteng Zhang, Wenzhe Tang, Colin F. Duffield, Lihai Zhang, Felix Kin Peng Hui, Yang Liu and Yanling Kang

856-873 A Competency Framework for Construction Engineering Graduates: An Industry Perspective

Engineering education plays a key role in training talent engineers to meet the challenges of sustainable development in the construction industry. To address the requirements of construction engineering and sustainable development, a new competency framework was developed based on a systematic literature review. This framework incorporates five categories of competencies, including interdisciplinary knowledge, technical expertise and innovation, identifying and solving problems, managerial capacity, and ethical and professional responsibilities. The framework was validated using a questionnaire survey and eight rounds of interviews. The results suggest that all the five competencies within the proposed framework are important and should be incorporated in the construction engineering education, and this can help graduates deal with sustainability issues in the future.

**Keywords:** sustainable development; competencies; construction engineering education; interdisciplinary education

Yujing Wang, Haimin Cao, Feng Xu and Jing Wang

874-883 The Influence of Educational Trust on the Willingness of Engineering Undergraduates to Participate in Academic Competition

Cultivating innovative engineers has become an important responsibility and mission of higher engineering education. Academic competition has emerged as an important carrier and means for the cultivation of innovative talents in engineering universities and colleges in China. However, the willingness of engineering undergraduates to participate in academic competition is low yet, which seriously reduces the effectiveness of innovative education in engineering universities. This study aims to investigate whether and how educational trust affects the willingness of engineering undergraduates to participate in academic competition. A questionnaire survey was conducted and 201 valid responses from an engineering and technical university in Shanghai were received. The collected data was analyzed by binary logistic model and research results show that in interpersonal trust, students' trust in their instructors and teammates has a significant positive influence on their willingness to participate in academic competitions. What's more, in institutional trust, students' trust in their schools has a significant positive impact on their willingness to participate in academic competitions, while their trust in competition organizers has no significant impact on their willingness. Finally, policy implications were proposed to improve the engineering undergraduates' willingness to engage in academic competition. This study provides valuable information for education authorities to make relevant policies to promote the cultivation of innovative talents in engineering universities and colleges.

**Keywords:** higher education; educational trust; engineering undergraduates; academic competition

Holly M. Matusovich, Andrew L. Gillen, Veronica Van Montfrans, Jacob R. Grohs, Tawni Paradise, Cheryl Carrico, Holly Lesko and Karen Gilbert

884-899 Student Outcomes from the Collective Design and Delivery of Culturally Relevant Engineering Outreach Curricula in Rural and Appalachian Middle Schools

Middle school is a pivotal time for career choice, and research is rich with studies on how students perceive engineering, as well as corresponding intervention strategies to introduce younger students to engineering and inform their conceptions of engineering. Unfortunately, such interventions are typically not designed in culturally relevant ways. Consequently, there continues to be a lack of students entering engineering and a low level of diverse candidates for this profession. The purpose of this study was to explore how students in rural and Appalachian Virginia conceive of engineering before and after engagement with culturally relevant hands-on activities in the classroom. We used student responses to the Draw an Engineer Test (DAET), consisting of a drawing and several open-ended prompts administered before and after the set of engagements, to answer our research questions related to changes in students' conceptions of engineering. We used this study to develop recommendations for teachers for the use of such engineering engagement practices and how to best assess their outcomes, including looking at the practicality of the DAET. Overall, we found evidence that our classroom engagements positively influenced students' conceptions of engineering in these settings.

**Keywords:** middle school; DAET; student conceptions of engineering

Juebei Chen, Anette Kolmos, Aida Olivia Pereira de Carvalho Guerra and Chunfang Zhou

900-914 Academic Staff's Motivation, Outcomes and Challenges in a Pedagogical Training Programme of PBL

PBL (Project-based/Problem-based Learning), as a core method of student-centred learning, has become a widespread teaching and learning methodology in higher education during the past 30 years because of its effectiveness in improving students' academic knowledge, teamwork skills, communication skills and leadership. However, the educational reform using PBL methods is a long-term task and also a challenge for engineering staff. In order to improve the PBL implementation, it is important to provide PBL pedagogical training opportunities for engineering staff. Taking an international pedagogical training programme as a case, this study illustrates academic staff's learning motivation, experience, outcomes and challenges in a pedagogical PBL training programme. Suggestions are proposed to optimise the design of pedagogical training programmes for engineering staff professional development to promote effective curriculum change processes.

**Keywords:** PBL; staff training and development; challenges; curriculum change

In this article, we discuss the incorporation of a course entitled “Creative Sound Workshop” into the Acoustic Engineering undergraduate curriculum at the Universidad Austral de Chile. The course was aimed at offering an experience of applied musical creativity to engineering students. We provide a detailed account of the process of curriculum design, with reference to the current literature on creativity and, more specifically, creative thinking in education. We also introduce the notion of “thinking dispositions”, in the light of which we discuss students’ performance on their final project: the design of a semi-autonomous interactive digital instrument using Pure Data, an open-source visual programming environment. Finally, we reflect on our experience of two years of teaching the workshop, and discuss how the course has been received.

**Keywords:** creativity; thinking dispositions; engineering education; course design; music creativity

Vasu Kumar, Michael D. Johnson, Bimal Nepal and Gourav Ghoshal 925-938 Impact of a High Value Manufacturing Research and Enrichment Experience on Self-Efficacy of High School STEM Teachers

The manufacturing industry is one of the largest employers in the US and plays a vital role in contributing to the US economic growth. The prospects of manufacturing growth and stability are the focus of many developed nations. However, the recent fast paced advancements in manufacturing technologies have created a void in the talent pool that requires a skilled workforce to fill in the gap. Prior research shows that the foundation of STEM education, including advanced manufacturing, is laid out during K-12 education. Further, high school teachers with higher self-efficacy beliefs are found to be more successful in generating interest and highlighting value of STEM education in their students. The prior research also reveals that, in addition to their self-efficacy beliefs, teachers’ perception of manufacturing can also impact interest among their students. To that end, this research aims to investigate the impact of an intervention program (an engineering research and enrichment experience) on the self-efficacy of the secondary teachers. Specifically, this study focuses on impact of an enrichment experience in engineering (E3) program designed for high school teachers to boost their engineering/manufacturing self-efficacy. The paper investigates the teachers’ understanding of manufacturing and how their perception about manufacturing changed after partaking in the E3 program. It uses the T-STEM instrument to evaluate the self-efficacy beliefs of E3 participants and to determine the effectiveness of the program. The paper also presents a comparative analysis of teachers’ self-efficacy between various population groups divided by gender, ethnicity, and school type. The survey results show that the E3 program improved the self-efficacy of the teachers across all the population groups although with some variations among the groups in the net gain in post program efficacy.

**Keywords:** High-Value Manufacturing (HVM); teacher self-efficacy; STEM education; K-12

Julianna Gesun, Robert Gammon-Pitman, Edward Berger, Allison Godwin and John Mark Froiland 939-959 Developing a Consensus Model of Engineering Thriving Using a Delphi Process

A large number of engineering educators, researchers, administrators, staff, and advisors have advocated to shift the narrative on engineering students from “surviving” to “thriving.” In this study, we developed a model of engineering student thriving based upon input from 47 experts participating in a Delphi process. The research question for this study is, “To what extent do experts agree on the completeness, conciseness, clarity, accuracy, and utility of the model on engineering student thriving?” The experts included engineering administrators, professors, staff, and advisors who had considerable experience in teaching, supporting, advising, mentoring, or working directly with undergraduate engineering students. Each round of the Delphi process provided opportunities for the experts to identify the most important components of engineering student thriving, the relationships among these components, and the assumptions (often tacit) regarding engineering thriving. After three rounds, our experts reached consensus on a model of engineering thriving that they considered complete, accurate, concise, clear, and useful. Findings from this study revealed three key components of engineering thriving: Internal thriving competencies, external thriving outcomes, and the engineering culture, systemic factors, resources, context and situation. First, undergraduate engineering students have direct and immediate control over only their internal thriving competencies, and our experts overwhelmingly agreed that engineering student thriving should focus more on non-cognitive competencies and non-academic outcomes. Second, the experts identified external thriving outcomes that include characteristics of well-functioning engineering students within the context and structures of the engineering system. However, these outcomes should not be used to determine whether an individual student is thriving, as they are not directly malleable. Third, the engineering culture, systemic factors, resources, context and situation is most directly influenced by the engineering program or institution. The experts agreed that this bridging component between internal competencies and external outcomes represents key concerns for engineering programs. We present highlights from each round of the Delphi process followed by applications of the model for engineering students, staff, administrators, programs, and institutions. These findings build upon prior research by broadening perspectives on engineering student thriving and can inform efforts to support holistic engineering student development.

**Keywords:** thriving; Delphi method; engineering education; student success; positive psychology

Nam Ju Kim, Jun H. Park, Sang-Eun Lee and Dimitris Timpilis 960-974 Impact of Prior Knowledge, Learning Style, and Problem Nature on Students Performance in a Flipped Engineering Mathematics Class

Although many studies have demonstrated the effectiveness of flipped learning in terms of performance enhancements, there is a lack of research investigating the factors that can affect students’ performance in introductory engineering mathematics courses using flipped learning. This study investigated how different factors, including prior knowledge, learning styles, and types of problems, can affect the flipped classroom students’ performance in engineering mathematics. Before and after participating in flipped learning covering the concept of ordinary differential equations, 139 engineering students’ testing and survey data were collected. The results showed that, first, two learning styles including converging and assimilating played a major role in problem-solving, and significantly predicted their final test score. Second, when engaging in real-life and non-routine problems individually or in collaboration with group members, students’ scores in the post-test were increased. This study concluded that instructors could enhance students’ performance in engineering mathematics by integrating flipped learning with their current curriculum, helping students apply the abstract concepts of mathematics to authentic situations, and considering students’ learning styles as a factor in successful flipped learning.

**Keywords:** flipped learning; prior knowledge; learning style; problem types; engineering mathematics

Megan Emmons and Anthony A. Maciejewski 975-986 Emulating a Career Experience At-Scale so Students Can Make Informed Decisions About Electrical Engineering Early in Their Academic Career

At Colorado State University, we are actively reinvigorating our Electrical and Computer Engineering (ECE) curriculum to increase diversity and retention. In Fall 2019, we implemented a novel, one-credit hour, career emulation course for first-year students considering a degree in ECE. The course was deliberately designed to help students imagine working as a professional engineer so they could make more informed decisions about their academic endeavors. Throughout the course, students were engaged in realistic engineering tasks and interacted with a diverse range of professional engineers. These experiences were created to ensure all students had the opportunity to visualize themselves in a professional engineering environment. Eighteen students were initially enrolled in the Fall 2019 implementation and a new cohort of 16 students enrolled in the Fall 2020 course offering. Course surveys, instructor observations, and discussions with students regarding their future career expectations were used to assess the effectiveness of the course. Based on these metrics, we achieved our primary goal of helping students make an informed decision about pursuing a degree in ECE by emulating informative workplace learning opportunities.

**Keywords:** first-year engineering; introduction to engineering; internship experience; engineering identity; non-technical engineering skills; career emulation

Virtual internships (VI) enable students, especially those in engineering domains, to gain real-world experience and skills in a remote online setting. Even though they offer several advantages over traditional internship programs, these benefits have not been fully realized due to many challenges related to organization, VI models, information technologies, communication, and collaboration. This paper introduces the specific VI lifecycle model and the methodology for VIs with practical workflows and guidelines, which enable design of adapted and flexible internship programs. For successful management of VIs, a web-based digital platform is designed and developed. It is based on the proposed VI lifecycle model and methodology, and it connects all parties (students, schools, and companies) within the secure and collaborative digital environment. Its architecture is multitiered and it is based on microservices and open standards, so it can be customized for specific VI scenarios, or integrated with other specialized e-learning platforms that complement VI user experience. The digital platform contains specialized components that support specific VI tasks, such as Internship database, Lectures, Assessments, Company Profiles, Assignments, etc. This enables more flexible, efficient, personalized, low-cost, and adaptive solutions for VIs. The proposed VI model and digital platform were successfully applied in several southeastern European countries, demonstrating applicability and flexibility of the approach. The results, based on various surveys and the system and user data from the digital platform, show a higher level of collaboration, better communication, increased level of professional knowledge, and acquired skills related to online teamwork and collaboration.

**Keywords:** virtual internship; web platform; internship model; vocational education and training

Soonhee Hwang 999–1012 The Role of Psychological Well-Being in Women Undergraduate Students' Engineering Self-Efficacy and Major Satisfaction

This research examined the role of psychological well-being in women undergraduate students' engineering self-efficacy and major satisfaction in Korea. To achieve this purpose, first, differences in psychological well-being, engineering self-efficacy and major satisfaction among engineering students were examined. Second, the relationships among psychological well-being, engineering self-efficacy and major satisfaction were investigated. In addition, the effects of psychological well-being, as perceived by men and women engineering students, on engineering self-efficacy as well as major satisfaction were explored. A total of 253 engineering students from one university in Korea responded to survey based on a three-variables scale. The findings were that, firstly, men students scored higher in all of the three variables including psychological well-being, engineering self-efficacy and major satisfaction, and that these gender differences were statistically significant. Secondly, a positive correlation among psychological well-being, engineering self-efficacy and major satisfaction was identified. Thirdly, psychological well-being predicted engineering self-efficacy and major satisfaction's sub-factors. The practical implications of these findings are discussed herein, with particular attention on education for promotion of psychological well-being, engineering self-efficacy and major satisfaction.

**Keywords:** women undergraduate students; psychological well-being; engineering self-efficacy; major satisfaction

Noemi V. Mendoza Diaz, Cijy Elizabeth Sunny, Trinidad Sotomayor and Jacques Richard 1013–1023 Time to Graduate for Latinos/Hispanics in Comparison to Other Diverse Student Groups: A Multi-Institutional/Multilevel MIDFIELD Study

Higher institutions of education represent the social mobility mechanisms that create more just societies. The STEM fields are particularly critical in the development of these modern, more just societies. In the United States, the social and racial justice debates are ever more relevant and present in academia. Studies focused on under-represented and under-served groups in education, especially STEM fields, are timely and of paramount importance. This is a study that analyzed student data of 19 institutions, concentrated in what is known as the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD). It utilized multilevel (HLM) analysis focused on the Time to Graduate outcome of under-represented populations, emphasizing the Latino/Hispanics group. Multilevel analysis is a powerful tool to evaluate differences in groups such as institutions and races/ethnicities, which is the type of data MIDFIELD affords. Results show that depending on the multilevel model, either fixed or random slope, there is a significant difference between the number of terms taken to graduate for under-represented groups, including Latinos/Hispanics, compared to White groups and for Black compared to White groups. This suggests that Black students tend to be more impacted by their institution than other racial/ethnic groups. Since the emphasis was Latinos/Hispanics, the question remaining is if these results transfer to a sample with more Latino/Hispanic representation.

**Keywords:** Multiple-Institution database; STEM, MIDFIELD; Latinos; Hispanics

Ariyo Samson Oluwatimilehin, Jimoh Bakare, Ede Emmanuel Okafor and Theresa Chinyere Ogbuanya 1024–1033 Enhancing Motivation of Electrical and Mechanical Engineering Technology Education Students with Acceptance and Commitment Therapy

The essence of studying electrical and mechanical engineering technology is to acquire relevant skills for production of goods and services. Students of electrical and mechanical engineering technology in various universities in Nigeria are not well motivated and this can be seen in their poor learning outcomes and quality of skills acquired while in schools. Various studies have been conducted on how various teaching methods can be used to enhance the motivation of students studying electrical and mechanical engineering technology education, however no research on how acceptance and commitment therapy can be used to enhance motivation of electrical and mechanical engineering technology education students and this study therefore becomes necessary. This is because students need to be motivated to acquire relevant skills for producing goods and services while in school and after graduation. The study was carried out in all three universities that offer Electrical and Mechanical Engineering Technology education in south-western Nigeria. The Academic Motivation Scale was used to select participants who scored low into the study. The intervention consisted of 6 weeks acceptance and commitment therapy and placebo treatment. Self-report questionnaire was used as data collection for the study. Mixed Model Repeated Measures (MMRM), independent-samples two-tailed t-tests, chi-square and process macro were used for data analysis in the study. The result of the study indicated that participants in the treatment group recorded gains in motivation across different time points when compared to the participants in the control group. Also, self-efficacy moderated the effect of acceptance and commitment therapy on motivation. The current study suggests that acceptance and commitment therapy can be used to enhance the motivation of electrical and mechanical engineering technology education students.

**Keywords:** acceptance and commitment therapy; motivation; self-efficacy; undergraduates; mechanical and electrical technology education

Ashraf Badir and Robert O'Neill 1034–1043 Self-Assessment of Homework Assignments in Civil Engineering Design Courses

Although the educational advantages of student self-assessment have been generally documented and introduced into different universities' courses, the use of self-grading as a formative assessment tool in engineering design courses, where unique solutions are not frequently the case, has not been exploited by faculty. This paper reports an experiment in which students (n = 216) in two civil engineering courses; namely a reinforced concrete design course and a steel design course, were assigned the task to self-grade their homework. The study provides a comparison of students and faculty/teaching assistants (TAs) assigned grades and recommendations for future adoption of self-grading in design courses based on lessons learned.

**Keywords:** formative assessment; self-grading; self-assessment; homework grading; student perceptions; design courses; life-long learning

**Mariana Tafur Arciniegas, Monica Isabel Gomez Velez, Juan C. Reyes, Diego M. Valencia, Francisco A. Galvis and Christian C. Angel** 1044–1059 The Impact of Non-Traditional Teaching on Students' Performance and Perceptions in a Structural Engineering Course

The Civil Engineering program at Universidad de los Andes, Colombia, redesigned its Structural analysis course to exploit the advantages of blended and flipped learning. The process focused on connecting the civil engineering education to professional practice throughout virtual field visits, hands-on activities, and real-world assignments and examinations. To evaluate the effects of the redesign on the student's learning experience, we conducted a multiphase mixed methods research (N = 329), which confirmed a positive impact on students' perceptions of their learning experience. Students value the greater availability of resources, considered to be a key factor to improve their learning. The redesign also promoted a greater interaction between peers and professors around problems closely related to professional engineering practice. Although we observed a lower final grade average, further analysis confirmed an increase in examinations difficulty and performance improvements when reviewing control test questions. Overall, the redesign had a positive influence on students and instructors by merging real-world problems with the classroom experience.

**Keywords:** blended learning; performance; student perception; learning environment; mixed methods research

**Belén Muñoz-Medina, Sergio Blanco and Marcos G. Alberti** 1060–1070 Impact of Service-Learning on the Motivation of Engineering and High School Students

Service-learning is a pedagogical methodology that enhances student's learning process through a community service experience. Since the first applications of this methodology in Engineering education in the 90s a great volume of evidence has been collected given its benefits in the students' personal learning and civic responsibility. In Spain, its development is relatively recent although there are already successful examples of application in several universities. In this study, a service-learning activity in the School of Civil Engineering of the Technical University of Madrid (Spain) is presented. In such activity, undergraduate and graduate students presented their final degree project to high-school students. Presentations were recorded and peer-reviewed by the university students along with their tutors. The main objectives of the study were: (a) measuring the degree of efficiency of this service-learning experience to boost Sciences, Technology, Engineering and Mathematics (STEM) vocations, (b) evaluating the degree of comprehension from the high-school students with the presentations made by university students, (c) improving the communication skills of the university students and (d) comparing the various feedback obtained from lecturers, teachers and both the high-school and university students. The conclusions showed that this activity was effective in capturing the interest of high-school students in studying STEM degrees. These high-school students actively engaged in the development of the activity showing a high degree of satisfaction. On the other role, university students stated that the activity helped them to improve their presentation skills. They have indicated that the two aspects of the project with the most impact have been: (a) being able to visualize their recorded video presentations and (b) reflecting through the evaluation process of their peers using a correction rubric. This critical reflection on the aspects to be evaluated in an oral presentation, applied to their classmates and to themselves, has been more useful than receiving different feedback from tutor teachers, high-school students and their own university colleagues. We understand that this activity is easily transferable to other technical schools and can benefit the oral communication skills of university students and boost STEM vocations among high-school students.

**Keywords:** service-learning; generic competences motivation; creativity; high school education; university education; written communication; oral communication

**Marko Sarac, Sasa Adamovic and Muzafer Saracevic** 1071–1079 Interactive and Collaborative Experimental Platforms for Teaching Introductory Internet of Things Concepts

The traditional approach to teaching computer system and IOT involves the presentation of a large amount of theoretical and mathematical data and materials to students. The common approach is a theoretical explanation of the principles, on the whiteboard and if possible, with the use of graphical animations. The main issue in this area is raising interactivity and getting collaboration between students on project assignments. In this paper, authors are proposing more interactive approach that could be beneficial to teachers of related subjects. Presented are the results of using software and simulating tools (in combination with Arduino hardware development solution) for teaching collaboratively and interactively courses related to IoT. The paper presents ideas for implementation of practical and experimental project assignments, student engagement and collaboration. The paper also presents the results of authors after applying this approach to one generation of students. The application access with practical assignments gave markedly better results, measured through student engagement, classroom attendance and distribution of student results. In this manner, the students had a better understanding of the basics of the microcontrollers, sensors, IoT and were willing to engage in programming of microcontrollers at the lower level. Students have also shown better results in closely related courses such as the courses of operating systems. In addition, some students continued to use IoT platforms for future projects (in college or practice).

**Keywords:** interactive approach; IoT computer science teaching; interactive teaching; computer science

**Aziz Shekh-Abad, Orit Hazzan and Aharon Gero** 1080–1089 Promoting Systems Thinking and Abstract Thinking in High-School Electronics Students: Integration of Dedicated Tasks into Project-Based Learning

Project-based learning is receiving ongoing attention in engineering education. Recently, emphasis has been placed on the importance of systems thinking and abstract thinking among high-school and undergraduate students. In light of the recently reported positive correlation between systems thinking and abstract thinking, the research described in this paper examined whether these two thinking skills could be promoted simultaneously through project-based learning that included dedicated tasks. The study, which used quantitative and qualitative tools, involved 36 high-school electronics students (Grade 12). According to the findings, a significant improvement (large effect) was achieved in both types of thinking. Specifically, the students adopted some of the systems thinker's and abstract thinker's features.

**Keywords:** project-based learning; systems thinking; abstract thinking; electronics students

**Laura J. Hirshfield and Debbie Chachra** 1090–1107 Complex Systems: Interactions Between Gender and Project Context on Confidence of First-Year Engineering Students

In first-year team-based engineering projects, students have the opportunity to become familiar with the field, gain knowledge and skills, and develop engineering self-confidence and self-efficacy. How engineering students gain (or lose) this confidence depends in part on the opportunities that they have to complete mastery experiences, in which they successfully complete tasks that allow them to feel more capable as engineers. However, all students may not be engaging similarly in mastery experiences, and thus, they may not experience the same benefits from the project experience. In this study, we focused on students enrolled in first-year engineering project courses at two different institutions, to investigate the differences that exist between the mastery experiences that they complete, their changes in engineering confidence and self-efficacy, how these two factors interact, and how these aspects are different depending on the student's gender identity. We found that although men started the semester with generally higher confidence and self-efficacy than women, this gap closed by the end of the course. In investigating the relationships between these changes in confidence and self-efficacy and the time devoted to different tasks, it was found that the engineering confidence of students generally benefited more from spending time on non-gender-stereotypical tasks; although it may seem counter-intuitive, spending more time on technical tasks is linked to a *decrease* in confidence for women. Finally, there were marked differences

between the women at each institution in how they spent their time or experienced changes in engineering confidence and self-efficacy. These results suggest that task choice and self-efficacy are sensitive to the learning experience in a way that *interacts* with student demographics, rather than student demographics being the dominant contributor to their experience in a project course; that is, while gender is a factor, the specific effects depend on the academic context.

**Keywords:** First-year engineering; project-based learning; self-efficacy; confidence

**Zhiliang Huang, Jielian Deng, Hongxu Zhou, Tongguang Yang, Shuguang Deng and Zhiguo Zhao** 1108–1120 Teaching Sustainability Principles to Engineering Educators

This paper is to provide experimental evidence of designing and assessing a teacher training program for sustainability competency enhancement in higher education. Eighty-five engineering teachers participated in the program comprising three stages of fifteen days. The first stage focused on the content knowledge of eco-design and how to apply the life cycle assessment (LCA) methods and tools. The second stage aimed at using the four-step LCA method to a power battery eco-design problem. The third stage was to create a general structured eco-design teaching approach for realizing its expansion in various engineering fields. The findings suggested that the participants enhanced their sustainability awareness and eco-design skills, and improved in the four elements of technological pedagogical content knowledge (TPACK) through the program. The analysis on participants' reflective essays indicated that improvement mainly comes from the stages of LCA practice and eco-design integration. This study validates the importance of focusing teacher professional development on sustainability awareness and eco-design skill.

**Keywords:** sustainability competency; eco-design; life cycle assessment; teacher training; engineering education

**Asem Majed Othman and Emad Hashiem Abualsauod** 1121–1130 Quality Assurance: Industrial Engineering Capstone Design Project Process Standardization

This paper presents a comprehensive overview of the Capstone Design Project (CDP) course guideline developed by an industrial engineering (IE) department at a public university. The ultimate objective is to create a stable reference point for faculty members and students to follow for the CDP. To this end, this paper presents a standardization process model for the CDP through the development of the Capstone Design Project Handbook (CDPH). The developed CDPH includes all of the requirements, details, course outcomes, and specifications necessary to ensure a standardized process and continuous improvement of the CDP experience. The purpose of this paper is to standardize and improve the process from registering for the CDP course to the posting of the grades at the end of the course. The outcome of developing such a document is the enhancement of the quality of the education received by the students. The CDPH will also provide the faculty members and students with deadline dates, assessment forms, evaluation criteria, rubrics, and deliverable requirements for the CDP journey. This study provides evidence related to the significant results experienced by the stakeholders who utilized the CDPH.

**Keywords:** Capstone Project Handbook; process improvement; process standardization

**Ronit Shmalo, Tammar Shrot and Neta Kela Madar** 1131–1143 Investigating Factors That Impact the Development of Entrepreneurial Interest among Engineering Students

Entrepreneurship is a crucial skill in today's world, especially in the engineering and hi-tech industries, but engineering education is still lagging behind in finding ways to teach entrepreneurship. The purpose of this study is to clarify the factors that contribute to entrepreneurship tendencies among engineering students and to use them as an entrepreneurship predictor tool. We conducted research on 95 undergraduate engineering students, for which we used well-documented personality analysis and entrepreneurial questionnaires. In particular, we analyzed the relationship between personality profiling and entrepreneurial intention, and we examined entrepreneurship according to the types of goals that drive innovative behavior. We discovered four main factors that contribute to entrepreneurial behavior: motivation, control, innovative personality, and ability to get support. In addition, our findings indicate that while emotional intelligence contributes to the engineering students' entrepreneurial intention, students with an established perception of gender equality have higher entrepreneurship intention. This suggests that their entrepreneurial tendencies will benefit from an enhanced perception of gender equality. The importance of this study is that it points out the crucial impact of the perception of gender equality in the early stages of student development in the academic world. This pinpoints the effect of gender equality on entrepreneurial and innovation intention. Therefore, it is crucial to examine how gender equality and emotional intelligence can be incorporated into the curriculum of engineering studies. The challenges of teaching entrepreneurship in engineering education as well as the difficulties of involving women as entrepreneurs can both be solved by actions that foster entrepreneurship for women in the educational setting.

**Keywords:** entrepreneurship; gender differences; entrepreneurial intention; personality factors; engineering education