

Contents

Section I

Special Issue

Ethics, Social Responsibility and Sustainability in Engineering Education

Guest Editors

Marc Alier Forment – Universidad Politécnica de Cataluña, Spain

Miguel Ángel Conde – Escuelas de Ingenierías Industrial e Informática, University of León, Spain

Editorial 583

Ahmad Ibrahim

Guest Editorial 584–588

Marc Alier Forment and Miguel Ángel Conde

Experimental Education of Collaborative Design. The Case of an Inclusive Bus Stop for a Tourist Transportation Hub 589–599

Manuela Pires Rosa

The design of transport infrastructures must be developed for social sustainability. Collective transport, interfaces and pedestrian infrastructures must guarantee a combination of quality characteristics, where accessibility according to the universal design approach is prominent. Universal and inclusive design must be consistent with user expectations and needs, and so, the associated process must involve people with disabilities and elderly citizens to understand their difficulties in using the built environment. This is the context of the research project Accessibility for All in Tourism (2017–2019), that focuses on the development of a pilot study of an accessible, smart and sustainable bus stop to be located at a tourist transportation hub. The research was developed considering the perspective of multiple users, professionals in the disability field, and experts who applied technical standards. This co-design process attended to different users' needs. It was a process that required a transdisciplinary approach by the team, integrating students and people with disabilities, walking and observing them and taking into account senior tourists' perceptions through an inquiry survey. This paper describes the collaborative approach that was developed with Civil Engineering students at the Institute of Engineering at the University of Algarve, influencing their work and knowledge. The results indicate that students perceived the concepts of universal design and inclusive design and designed the bus stop for social sustainability. An inclusive society requires input from different users of the built environment and knowledge of their specific needs by engineering designers. Pedestrian infrastructure and interface design demand user-centred approaches and so, processes of co-creation with communities.

Keywords: accessibility for all; co-design; bus stop; users; education; social responsibility; sustainability

Teaching Essential Competencies for Social and Sustainable Engineering Design – Case Study of a Research-Oriented Master's Seminar 600–610

Ann-Kristin Winkens and Carmen Leicht-Scholten

The master's seminar "Competencies for Social and Sustainable Engineering Design" at RWTH Aachen University is part of the study programs Environmental Engineering, Civil Engineering and Industrial Engineering. Focusing on Education for Sustainable Development (ESD), this course covers, teaches and reflects relevant competencies for socially responsible and sustainable engineering design. Following a research-orientated focus, the following research question was addressed: "Which competencies are considered relevant by future engineers in the context of sustainable and socially responsible engineering design?". The purpose of this paper is to present this approach and, on the basis of the seminar, to explain how relevant competencies for socially responsible and sustainable engineering design can be acquired by engineers. Moreover, the seminar concept is explained and a methodology for teaching the aforementioned topics is described that can also be transferred to other courses. The evaluation of course-specific feedback allows to present both conclusions and corresponding solution approaches, as well as challenges associated with the concept. Results show that engineering students call for competencies which go beyond pure technical knowledge, and, at the same time, determine that these competencies, like social competencies, are missing in their studies. Accordingly, this leads to implications for future curricula development.

Keywords: engineering education; engineering skills; competencies; sustainability; responsibility

Engineering Faculty Views on Sustainability and Education Research: Survey Results and Analyses 611–620

Paul Gannon, Ryan Anderson, Carolyn Plumb, Douglas Hacker and Kerry Shephard

Increasing interests in both engineering education research and sustainability education motivated development of a survey instrument aimed at measuring engineering educators' attitudes and dispositions toward these endeavors. An online survey instrument was distributed to engineering faculty and instructors at a medium-sized land-grant university within the United States, with results briefly summarized in the 2017 Conference Proceedings of the American Society for Engineering Education (ASEE). The survey is presented here in its entirety, along with statistical analyses of the previously summarized results and discussion of responses to open-ended items. The survey instrument was effective in measuring engineering faculty support toward both engineering education research and sustainability education. The survey items also factored to measure attitudes toward climate change, teaching practices and curriculum as well as use of research-driven pedagogies. Statistical analyses of the survey structure are also presented along with suggestions for its further development and potential use.

Keywords: engineering faculty attitudes; sustainability education; survey development

Ester Gimenez-Carbo, M. Esther Gómez-Martín and Ignacio Andrés-Domènech

The paper presents and analyses how the generic outcome “Ethical, environmental and professional responsibility” is achieved in the bachelor’s degree in civil engineering at Universitat Politècnica de València (Spain). The analysis is based on the study of activities and evidences generated when assessing this outcome, interviews with responsible lecturers for courses developing this generic outcome and opinions from final year students. The aim of the study is to determine whether the activities carried out during the bachelor’s degree ensure that students have been trained enough to achieve the two proficiency levels of this generic outcome. Conclusions are drawn and recommendations established to ensure that all graduated students achieve this essential learning outcome.

Keywords: generic outcome; ethical responsibility; professional responsibility; civil engineering; transversal skill

Embedding Ethics Throughout a Master’s in Integrated Engineering Curriculum

631–642

Sarah Jayne Hitt

The New Model Institute for Technology and Engineering (NMITE) in Hereford UK is a higher education start-up established to deliver a new age of engineering education. Because humanity’s pressing problems are inherently interdisciplinary, NMITE’s first degree, the Master’s in Integrated Engineering (MEng) integrates conventionally separate strands of engineering and goes still further – integrating engineering with other disciplines such as arts, humanities, business, and ethics. The intentional and strategic process by which the course content was developed enabled the creation of an ethics curriculum that maps onto and is embedded within each of the MEng’s 27 engineering modules. NMITE’s ethics curriculum has several distinctive components including an ethics spine approach that is scaffolded according to stages of ethical learning development and is embedded in problem-based learning pedagogy. This paper will describe the ethics interventions within NMITE’s MEng curriculum and will present autobiographic and self-reflective data from a pilot study of trial learners that contributed to an iterative process of improvement and acted as a guide to decision-making. NMITE’s thorough and robust approach to embedding ethics within and throughout its Master’s in Integrated Engineering has the potential to enable engineers to promote social responsibility and sustainability, to fulfil their public duty, and to engage in lifelong learning and reflection.

Keywords: integrated engineering; engineering ethics education; ethics pedagogy; curriculum development

Teaching Topics of Responsibility and Sustainability in Large Engineering Classes

643–655

Marie Decker, Ann-Kristin Winkens and Carmen Leicht-Scholten

Introducing engineering students to topics of social responsibility and sustainability in the field of science and technology studies is internationally discussed, but there is little common consensus on best practices. Especially in large and mandatory engineering courses, initiating reflection processes among the students imposes difficulties on lecturers. The lecture “Engineering and Society” is attended each year by about 500 engineering students at RWTH Aachen University in Germany. Intended to familiarize engineering students with central theories and topics in the field of science and technology studies as well as sustainability and responsibility, the lecture creates a contrast to the highly technical engineering contents in these study programs. To increase the accessibility of these topics for students, a detailed teaching concept was developed by the authors which is reviewed in this paper. The paper proposes this approach for teaching sustainability and responsibility to engineering students in a large mandatory bachelor’s course as well as raising awareness for their own responsibility while maintaining focus on the academic content of the lecture. The paper aims to answer the following research questions: How to teach sustainability and responsibility to engineering students in a large mandatory bachelor’s course? How to raise awareness for personal responsibility as engineering students? Challenges and possible solutions related to the academic content of sustainability and responsibility are discussed based on evaluation outcomes and lecturers’ experiences.

Keywords: engineering education; blended learning; teaching large classes; sustainability; RRI

Integration of Ethics, Sustainability, and Social Responsibility Components in an Undergraduate Engineering Course on Finite Element Analysis

656–662

Gaganpreet Sidhu and Seshasai Srinivasan

In this work, we use a series of case studies to introduce ethical thinking, environmental sustainability, and social responsibility in a level 3 undergraduate engineering course. Specifically, in teaching the principles of Finite Element Analysis, used to perform engineering and performance analysis of designs, we introduce several real-world engineering ethics situations closely connected to the technical topics taught in the class. In taking up each case, the instructor provides a context, and the underlying micro-ethics and macro-ethics dilemmas are outlined. Students in two different cohorts are given the same problems. In the first cohort, the students submit an individual commentary following an analysis and self-reflection. In the second cohort, the students prepare a commentary in groups following a detailed deliberation between the peers. From the analysis of the commentaries of the two cohorts, we found that students in the second cohort had more evolved and rich commentaries. This cohort demonstrated a more developed moral imagination, significantly stronger ethical reasoning skills due to the exchange of ideas and knowledge between their peers, and facilitation by the faculty member. We also found that these debates and discussions help students hone their negotiation, strategic planning, public speaking, and evidence-presenting skills. Students also learn to empathize with peers’ views and opinions, honing their collaboration and teamwork abilities while arriving at a consensus on open-ended problems.

Keywords: ethics, sustainability; social responsibility; finite element analysis; engineering curriculum

A Case Study in Brazil and Spain about the Students’ Perception of the Gender Gap in Computing

663–672

Alicia García-Holgado, Carina S. González-González, Ismar Frango Silveira and Francisco J. García-Peñalvo

Foster diversity and inclusion are part of the strategic actions of public and private organizations. Some of these actions are focused on increasing the representation of historically underrepresented groups and investing in creating a culture where all employees can reach their potential. Moreover, there are sectors in which the lack of inclusive environments is more critical. In particular, in the engineering and technology sectors, there is a lack of diversity related to gender and race. This problem is present in all worldwide regions, despite vary from one to another. Regarding the gender gap, governments and organizations put their efforts into reducing it in engineering and technology through actions mainly focused on engaging more women into these areas, avoiding dropping out during STEM studies, and joining the labor market. In this context, we have developed a project to mainstream gender within this framework and foster diversity in computer engineering studies. The project has two main objectives: prepare students to introduce diversity and inclusion as part of the software development processes; and build work environments that follow the principles of diversity and inclusion. In order to improve the actions related to both objectives, this study collects the perception of students regarding the gender gap in computer engineering studies to answer two questions: R1 – What kind of support do computer engineering students have before starting their university studies?; R2 – Are there differences between the perception of the students in Brazil and Spain related to the social, academic, and professional context? The results show that almost half of the participants had not received any support before studying Computer Engineering. On the other hand, mothers are the principal support in both countries. Finally, the results show that Spanish participants have more awareness of the lack of women in the engineering and technological sector and the need to work on this issue.

Keywords: gender gap; computer engineering; women; quantitative analysis

Project management is part of the Engineering curricula worldwide. Frequently, project management courses are goal-centered in the pursue of a balance in the triple constrain formed by quality, cost and schedule. However, ethics, social responsibility and sustainability play a crucial role on the development of projects since their success relies on compliance with laws, regulations and local culture and values. This paper presents an in-depth analysis on the treatment of ethics, social responsibility and sustainability according to two widely-used project management standards, Project Management Book of Knowledge (PMBok) and Individual Competence Baseline for Project, Program & Portfolio Management (ICB). We design an analytical framework to carry out a desk research to these two project management standards. Particularly, we count the number of times of appearance, present the definition, if any, determine the appearance in the different knowledge areas and process groups for PMBoK and in the different competences for ICB, and identify the proposed techniques or tools for ethics, social responsibility and sustainability management. The findings of the research demonstrate that ICB treats the three concepts more in deep than PMBoK. PMBoK refers more often to ethics and only proposes one tool for sustainability. ICB introduces the concepts throughout the standard, with repeated references to their significance. Nevertheless, the detail that standards provide can be further elaborated. As a result, we also suggest improvement proposals that could enhance the important role of these topics for students and practitioners involved in project management.

Keywords: project management; project management standards; ethics; social responsibility; sustainability

Team-Based Learning to Improve Diversity and Inclusion of Environmental Engineering Students: A Mixed Methods Case Study 684–694*Hong Yang*

In engineering education, numerous ranges of diversity are needed. With the growing number of international students, it is essential to enhance the inclusion in higher education. Team-based learning (TBL) has been applied in engineering education to boost diversity and inclusion. This study applied a mixed methods approach, a combination of quantitative (questionnaire) and qualitative (interview) methods, to research the effect of TBL on the diversity and inclusion of Chinese students and British students in the Environmental Engineering programme at one UK university. Nearly 70% of Chinese students considered their learning experiences with British students to be positive or very positive. Approximately 64% of students believed that they learned most when they were “discussing and preparing group seminar work/presentation together in library/classroom/other places”. “Enjoying a different culture” and “Learning from others with different educational backgrounds” are two primary reasons for Chinese students liking learning with British teammates. The interviews indicated substantial beneficial effects of TBL on enhancing diversity and inclusion in engineering education. Many students welcome the difference and consider it an opportunity to comprehend the foreign culture. The research results shed light on that embracing diversity and producing an inclusive setting have favourable effects on the academic and social development of engineering students. The COVID-19 pandemic exacerbated racism in some areas. Due to international travel restrictions, most international students have to study online. Further studies are required to understand the new challenges brought about by the pandemic.

Keywords: team-based learning; environmental engineering education; diversity; inclusion; China; UK

Exploring the Relationship between Students' Trait Empathy, their Attitudes Towards Sustainability, and their Reflections on a Workshop on Sustainable Design 695–708*Rohan Prabhu, Elizabeth Starkey and Mohammad Alsager Alzayed*

Now more than ever before, there is a need for engineering solutions to global environmental problems. Towards this need, we see an increase in efforts towards incorporating sustainability into engineering education and particularly in engineering design education. Despite this work, there remains the need to investigate the influence of these interventions on students' individual differences, especially their trait empathy and attitudes towards sustainability. Such an investigation is important as these individual differences could influence students' ability to relate to sustainability-focused issues and act upon them. Consequently, our goal in this paper is to investigate this research gap by exploring the relationship between students' individual differences – specifically, their trait empathy and attitudes towards sustainability – and their reflections on a sustainable design workshop in relation to a semester-long design project. Towards this goal, we conducted an exploratory study with 40 first-year engineering students from a large public university in the northeastern United States. The main findings from this study indicate the positive impact of participating in the sustainable design workshop on students' attitudes and intentions towards sustainability in addition to their perceived positive experiences with the workshop. These findings could inform future efforts towards devising pedagogical interventions that encourage a sustainability-focused mindset among engineering students, through engineering design education.

Keywords: engineering design education; sustainability; empathy; student experiences

Imagination and Moral Deliberation: A Case Study of an Ethics Discussion Session 709–718*Yousef Jalali, Christian Matheis and Vinod Lohani*

Despite the important advances in engineering ethics education, key problems with mainstream engineering ethics instruction have not been completely addressed. One critical aspect that has been overlooked in engineering education literature is the role of imagination in our moral deliberation. The lack of attention to one's values, background and experiences, treating mind and body as two separate entities, and downplaying the role of imagination as merely an emotional regulator, contribute to neglect for imaginative rationality one may engage in dealing with moral problems. We designed and implemented an ethics discussion session as part of the professional development activities in a National Science Foundation's Research Experiences for Undergraduate (NSF REU) program, in which we prioritized imagination as an essential character of moral reasoning and deliberation. In this paper, we describe the theoretical perspectives, the innovative ethics curriculum, and evaluation methods. Finally, we conclude with the results and reflection on the connection between the conceptual foundation and instructional choices.

Keywords: engineering ethics; pro-imaginal ethics; imagination; moral reasoning; innovative ethics curriculum

Stereotype Threat and Faultlines Based on Cultural Diversity in Engineering Education in Germany 719–726*Edwin Semke, Wanda Theobald and Petia Genkova*

This study is concerned with the evaluation of cultural awareness and its impact on student life at two German technical universities. Since the government is advertising internationally for students to come study in Germany, we were interested to find out, whether diversity is already fully accepted or needs more attention. In the interviews conducted it turned out that the general self-assessment of cultural diversity is rather low, especially among German students. Furthermore, we discovered that there seem to be differences between universities in small-scale and large-scale towns regarding stereotype threat and faultlines. Interaction and confrontation are crucial measures to reduce stereotype threat and faultlines among student groups. Faculty staff and institutional stakeholders must pay more attention to enhancing and empowering an awareness for cultural diversity as a key skill for future business life.

Keywords: cultural diversity; stereotype threat; faultlines; higher education; STEM

Kauser Jahan, Stephanie Farrell, Harriet Hartman and Tiago Forin

The Department of Civil and Environmental Engineering (CEE) at Rowan University received an NSF RED (Revolutionizing Engineering Departments) grant. A significant focus of this grant is to develop and integrate inclusive curriculum for core civil engineering courses. All core civil engineering courses at the sophomore and junior level are a part of this initiative. Courses included statics, solid mechanics, civil engineering systems, surveying, structural analyses, steel design, fluid mechanics, water resources engineering, material science, civil engineering materials, geotechnical engineering, environmental engineering, sustainable civil and environmental engineering and transportation engineering. The NSF RED initiative was integrated with our CEE goes Green efforts that were initiated in 2004. This initiative allowed the above mentioned courses to incorporate concepts and content on sustainability. Course content included strategies such as faculty training, presenting case studies, rewording course syllabi and problems, assigning team projects, developing extra credit projects. The success of this integration is measured via course evaluations, focus group responses and senior exit interviews. The early assessment data indicates that the strategies for revising course content is successful as the student responses are extremely positive for all courses across the border. Seventy five percent or more students responded favorably to the questions posed for the select courses except for statics, solid mechanics, civil engineering systems and transportation engineering. The courses for the structural engineering sequence (statics, solid mechanics, structural analyses, steel design and transportation engineering) indicated lower scores in comparison to the environmental and water resources engineering courses. The major challenge is to train adjunct or temporary faculty who teach select sections of the core courses when the need arises. Students in the junior year are subject to multiple surveys that leads to survey fatigue.

Keywords: inclusive; pedagogy; sustainability; civil engineering

Leveraging Sustainability to Teach About Social Justice in Civil Engineering Curricula

742–755

Tom Siller, Rebecca A. Atadero, A. M. Aramati Casper and Christina H. Paguyo

Sustainability is a vital interdisciplinary concept to address within engineering education. Furthermore, the natural connections that exist between sustainability and social justice provide an optimal opportunity to integrate both into curricula. We argue that engineering curricula ought to include sustainability and social justice so future engineers are trained to understand both societal and technical implications of their work, while acknowledging the challenges engineering faculty may face in conceptualizing social justice or social sustainability. We then highlight how new sustainable design rating systems, such as Envision and The Living Building Challenge, embed inclusion and social justice into their ratings and how these sustainability rating systems can help engineering faculty bring social justice into their classrooms in ways that meaningfully link to engineering content. Finally, we present two examples of how sustainability and social justice can be incorporated into the civil engineering curriculum through inclusive pedagogy and new curricula: (1) a semester-long effort to document, design, and improve the inclusive pedagogical practices in a first-year engineering course that included the theme of sustainability throughout much of the class meetings; and (2) a new assignment about the Envision rating system and the societal implications of rebuilding a major component of regional infrastructure. We conclude with recommendations that other instructors can use to begin incorporating social justice in their courses.

Keywords: diversity and inclusion in engineering education; good practices; methodologies and tools for including the principles of ethics; social responsibility; sustainability in engineering education

Section II

Contributions in: STEM, Teamwork, Psychological Safety, PBL, Big Data, Gender, Identity, Industry Skill Gap, Apprenticeship, Competencies Progress, Learning Modules, Computer Science, Manufacturing Engineering, Fluid Mechanics

Development and Evaluation of an Approach for Integrating Data Science Concepts into High School STEM Curriculum

756–773

Vytautas Štuikys, Renata Burbaitė, Giedrius Ziberkas and Ramūnas Kubiliūnas

Currently STEM education evolves rapidly towards a higher integration either among separate constituents (Science, Technology, Engineering and Mathematics) or by adding the new aspects, such as social. This paper aims at extending the science dimension in STEM-driven Computer Science (CS) education by integrating (through modelling) Data Science (DS) concepts into the high school curriculum. Three types of models and modelling (conceptual, feature-based, and physical modelling) incorporated into a coherent methodology form the background of the proposed approach. Models and modelling, as well processes with data, are essential attributes of engineering education too. The core result of this paper is a novel three-layered framework outlining a series of modelling processes to support integration along with the assessment model. The latter includes the Revised Bloom's taxonomy combined with computational and scientific thinking skills. The use of this approach in the real educational setting and provided experiments show that discovered models ensure a seamless integration of the DS component into STEM-driven CS education. This approach contributes to the increased students' motivation to learn due to the interesting real-world task and active learning of engineering aspects through constructing and testing own experimental system and data processing. The approach also enforces the learner's interdisciplinary knowledge by computational, scientific, and designing skills so important for engineering activities.

Keywords: STEM; computer science; data science; modelling and integration

Dynamics of Mixed-Gender Teams in Engineering Education

774–785

Behzad Beigpourian and Matthew W Ohland

Women are minoritized in U.S engineering programs and most engineering classrooms, and a variety of evidence indicates that they face inequities in team interactions. To reduce the impact of these inequities, some research indicates that instructors should avoid isolating women in engineering teams. While there are studies of mixed-gender teams in engineering education, most have focused on team performance and the team's final product, peer evaluation ratings, leadership self-efficacy, and the mode of collaboration. No comprehensive study of the dynamics of mixed-gender teams could be identified in the context of engineering education. This study investigates multiple measures of team dynamics holistically in mixed-gender teams: peer ratings, task interdependence, conflict, psychological safety, and satisfaction. Further, this research explores the extent to which women's satisfaction improves if their male teammates have similar characteristics (e.g., race/ethnicity and citizenship status) and how the women's satisfaction is related to the GPAs of their male teammates. The participants of this study were enrolled in a first-year engineering course, who provided information about various team dynamics four times during their teaming process. Mann-Whitney U tests were used to explore differences in team dynamics between mixed-gender teams and all-male teams. A multiple regression model was used to predict the women's team satisfaction based on their male team members' characteristics. Mixed-gender teams reported higher levels of task interdependence, but reported similar levels of conflict, psychological safety, and satisfaction. Women tended to be more satisfied when they worked with men who have similar citizenship status (based on class demographics, domestic women are more satisfied if their male teammates are also domestic). The results of this study include recommendations for instructors to improve team formation and facilitation.

Keywords: teamwork; mixed-gender teams; team formation; team dynamics; satisfaction; psychological safety; conflict; interdependence

In this paper, we explore how to apply Problem-Based Learning (PBL) to enrich the design of interdisciplinary education programs and facilitate the integration of big data engineering education into business contexts. Theoretically, we take social constructivism as the theoretical root of PBL, which highlights principles of student-centered learning, active learning, learning by doing, group learning, teachers' facilitation of the learning process, etc. In designing an education program, it is necessary to align diverse elements of PBL, including (1) objectives and outcomes; (2) types of problems, projects, and lectures; (3) progression, size, and duration; (4) students' learning; (5) academic staff and facilitation; (6) space and organization; and (7) assessment and evaluation. This leads to a discussion of a case on developing a new Bachelor of Education program of "Big Data + Business Administration" at Northeastern University (NEU), China. The case shows how PBL is applied in practice for the development of interdisciplinary engineering education and reflects how NEU managed institutional and cultural challenges in the process of changes. This paper provides implications for better developing interdisciplinary engineering education in the future.

Keywords: interdisciplinary education; program design; problem-based learning (PBL), big data education; business education

How Engineering Identity of First-Year Female and Male Engineering Majors is Predicted by Their Physics Self-Efficacy and Identity 799–813*Yangqiting Li and Chandralekha Singh*

Physics courses are important for engineering students because not only are they the foundation for many engineering courses, but students' physics motivational beliefs such as self-efficacy and identity may also influence their engineering identity as well as their choice of careers. In this study, we investigated first-year undergraduate engineering students' engineering identity and how it is predicted by their physics motivational beliefs (including physics self-efficacy, interest, perceived recognition and identity) in a calculus-based introductory physics course at a large research university in the US. We first investigated how these motivational beliefs change from the beginning to the end of the course (i.e., from pre to post) using descriptive statistics. Then, we investigated the predictive relationships among these motivational constructs using structural equation modeling (SEM). The SEM analysis revealed that students' engineering identity is predicted by their physics self-efficacy and identity. However, the descriptive statistics results showed that both male and female students' physics self-efficacy and identity decreased from pre to post, and female students' physics self-efficacy dropped even more than male students' did. Although students' average score on engineering identity also decreased from pre to post, this change was only statistically significant for male students. Our results show that students' physics perceived recognition is the strongest predictor of physics identity, and it also predicts students' engineering identity through physics identity and self-efficacy. We note that even though there were significant gender differences disadvantaging women in all motivational constructs studied, gender does not directly predict engineering and physics identities, which means that the gender differences in both identities are mediated through physics self-efficacy, interest and perceived recognition. Thus, in order to boost students' engineering identity, it is important to create an equitable and inclusive environment for learning physics, in which all students feel recognized and supported appropriately and develop a stronger physics and engineering identity.

Keywords: gender; self-efficacy; identity; perceived recognition; equity

Integrating Hands-on Continuous Process Improvement Practices with Traditional Manufacturing Processes Lab 814–824*Truc T. Ngo, Paul J. Wiold and Troy T. Bui*

Hands-on continuous process improvement and ability to train others are highly desired industry job skills for industrial and systems engineering (ISyE) graduates. It is important for higher education institutions to continuously strive for innovative curriculum and prepare their students adequately for industry. Traditional ISyE curricula typically involve fewer equipment and instrumentations compared to other engineering disciplines. As a result, ISyE students are often trained by using software, simulations and conceptual projects. To bridge the hands-on skill gap in our graduates, a new integrated manufacturing processes lab instructional pedagogy was introduced to ISyE juniors. In the new curriculum model, students were provided with the opportunity to apply continuous process improvement concept to traditional manufacturing processes while learning basic manufacturing operations and machine tools. Students either implemented their own continuous process improvement ideas on self-designed products, or trained other peers to execute their improvement proposals. A survey was conducted at the end of the lab course to assess students' experiences with the new lab curriculum and their perception of industry job skills. Results show that students highly valued the new learning experiences in the manufacturing processes lab course and wished to have more similar opportunities in their ISyE courses. Data also reveals that student perception of hands-on continuous process improvement skill and ability to train others were consistent with industry expectations with respect to the level of importance. However, students perceived the ability to train others to be more highly desired by their potential employers compared to the hands-on continuous process improvement skill, whereas industry shared the opposite expectation. The outcome of this study encourages the implementation of an integrated curriculum and instructional pedagogy model in which hands-on training of cross-cutting concepts is incorporated into traditional courses. Several areas of course improvement was also identified at the end of the study to further increase the effectiveness in preparing ISyE graduates for careers in industry.

Keywords: hands-on learning; industry skill gap; continuous process improvement; industrial and systems engineering; manufacturing processes; undergraduate lab curriculum

Comparison Between Apprenticeship Learning and Traditional Learning in Students of Mechanical Engineering Vocational Education: A Case Study in Slovenia 825–835*Martin Pivk and Boris Aberšek*

The objective of the work is to present a longitudinal study that examines the impact of teaching approaches on occupational skills and competencies and the possibility of further education or employment. We compared two groups of students taught according to the same curriculum. The first group (N = 25) learned according to the apprenticeship learning style (apprentices), and the second group (N = 19) learned according to the school-based learning style (students). We found that apprenticeship students with better average results at the end of compulsory education enrolled in the apprenticeship style of education, but the differences were not statistically significant. Students had higher average grades in the first year than apprentices, but apprentices had higher average grades in the second and third year. In the third year, the differences were statistically significant. There was no statistically significant difference between the average grades of the final exam. This study concludes that different educational styles do not have a relevant impact on vocational skills and competencies when the curriculum is the same. This is the first comparative case study and the basis for other studies. Apprenticeship enables also equal opportunities for further education and a faster transition from school to work. It is indispensable for all those who are considering or have already begun to implement apprenticeship.

Keywords: vocational education and training (VET); upper secondary education; apprenticeship; work-based learning; school-based learning

Progress of Student Competencies from Cornerstone to Capstone Design: A Longitudinal Study 836–848*John Crepeau, Michael Maughan, Steven Beyerlein, Dan Cordon, Matthew Swenson, Daniel Robertson and Sean Quallen*

Using a rubric which measures student design competencies from pre-engineer to professional engineer levels, we assessed 104 cornerstone, 96 mid-program and 97 capstone final design projects over a five-year period to monitor student performance. The competencies chosen were System Design, Implementation, Project Management and Documentation. Each competency mapped to a separate ABET student outcome. The results showed a marked improvement as students progressed through the curriculum. The

greatest improvement was shown in the System Design competency, followed by the Implementation, Project Management and Documentation competencies. The results provide an overview of evolution in design skills from cornerstone to capstone design and help identify areas of improvement within the design curriculum. The data also show that over the academic years 2016–2017 and 2017–2018, the 58 students who completed all three design courses and whose final design projects were assessed, scored consistently higher in each of the competencies on the assessment rubric than the 81 students who took only the cornerstone design course or the 38 students who took just the cornerstone and mid-program design courses. This suggests that those who scored higher marks in the cornerstone design course had a higher probability of passing the capstone design course and successfully graduating from the program.

Keywords: design based learning; rubric; assessment tools

Effectiveness of Hands-on Desktop Learning Modules to Improve Student Learning in Fluid Mechanics and Heat Transfer across Institutions and Program Types 849–872

Aminul Islam Khan, Negar Beheshti Pour, Kristin Bryant, David B. Thiessen, Olusola Adesope, Bernard J. Van Wie and Prashanta Dutta

Low-cost desktop learning modules (DLMs) were created to aid in student comprehension of a variety of engineering concepts. The DLMs are hands-on apparatuses that can be used to represent the theories behind the many process units seen in the industry. Activities associated with these modules may be used as a supplement to lecture materials. DLMs have initially been found to be effective within a classroom setting. Furthermore, intensive awareness has been gained through presenting results in reputable journals and conferences. However, the pedagogy associated with DLMs will not reach its full potential without translating to or propagating within the creator and outside institutions. To examine the translatability and disseminability of the DLMs, the modules were implemented in the chemical and mechanical engineering courses at several universities. In this paper, student assessment results from those beta implementations are discussed in light of several learning theories including Bloom's taxonomy and cognitive load theory. Moreover, the various aspects of DLMs including ease of use, flexibility, and complexity were evaluated by an expert panel composed of professors who teach transport phenomena-related courses to meet the adoption criteria of a new teaching/learning method. Results indicate that, regardless of the variation in the learning environment and implementation procedures, DLMs are useful for understanding key fluid mechanics and heat transfer concepts. Furthermore, the majority of the experts surveyed for this study are in favor of incorporating DLMs into the classroom. Based on these results, we expect DLMs will gain widespread interest and will be useful across curricula.

Keywords: desktop learning modules; hands-on apparatuses; venturi meter; heat exchangers; learning assessment