

## Contents

## Section I

## Special Issue

## Mould Breaking Responses to the Unprecedented Challenges in Engineering Education

## Guest Editors

Gail Krantzberg, Faiez Alani, and Seshasai Srinivasan

McMaster University, Hamilton, Ontario, Canada

**Editorial** 499  
*Ahmad Ibrahim*

**Guest Editorial**  
*Gail Krantzberg, Faiez Alani, and Seshasai Srinivasan* 500–501

**An Investigation into the Current Status and Importance of Sustainability Education for Designers and Engineers** 502–518  
*Emelia Delaney and Wei Liu*

Sustainability has become increasingly important globally, due to climate change, and has become a key focus within New Product Development (NPD), drawing attention from academia, media, and industry. The increase pressure to be more sustainable as a humanity and within industry has led to the identification of the need to ensure that students are suitably educated on key sustainability issues related to their field. This paper shows that design and engineering education, with a focus on sustainability issues, currently being taught in university is having an impact on industry. Previous literature has highlighted gaps within the knowledge which could better the teaching in this area. The paper proposes a framework which aims at facilitating the adoption of the teaching and learning of sustainability within design and engineering undergraduate education, specifically focusing on the overall impact of their future positions within the NPD process. The main goal of the framework is to support students and educators in the learning and education of key sustainability issues throughout the typical undergraduate degree period, focusing on teaching methods and key themes which will be valuable as students' progress into industry. Future Research objectives have also been outlined.

*Keywords:* sustainability; sustainability education; design; engineering

**Exploring the Effects of Variations in the Timing of a Sustainable Design Educational Intervention** 519–534  
*Mohammad Alsager Alzayed, Elizabeth Starkey and Rohan Prabhu*

The accelerating depletion of natural resources has brought environmental sustainability to the forefront of engineering and therefore, design educators must integrate sustainability into the engineering design curriculum. Several researchers have proposed educational interventions and design tools for sustainable design education. The timing of introducing such interventions, particularly in project-based courses, could influence the effectiveness of these interventions, and these effects remain largely unexplored. Our aim in this research is to investigate this research gap through a mixed-methods experiment conducted with first-year engineering design students. Specifically, we introduced a two-day module on sustainable design either in the first or sixth week of an 8-week long design project. The effects of this variation were compared by analyzing (1) changes in students' trait empathy, (2) changes in their beliefs, attitudes, and intentions towards sustainability, and (3) their responses to a reflection assignment collected at the end of the semester/design project. From the results, we see that the timing of the sustainable design intervention did not relate to changes in students' trait empathy or their beliefs, attitudes, and intentions towards sustainability. However, students from both timing conditions reported significant increases in their attitudes and intentions towards sustainable action. Finally, students who received the intervention later more frequently mentioned the use of sustainable design heuristics in their reflection responses. Taken together, these findings suggest the need for educators to consider the timing of sustainable design interventions, especially when integrating them into longer project-based courses.

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

**Perspectives of Advanced Biotechnology Undergraduates on the Effect of Case-Based Learning on their Individual Academic Achievements** 535–541  
*Faiez Alani and Rehmat Grewal*

Case-based learning (CBL) is an active learning modality customarily underutilized in the undergraduate engineering technology education. The prime purpose of this pedagogical study was to analyze student perspectives on the effect of CBL on their individual learning in the undergraduate advanced biotechnology course completed in fall 2019. The resultant findings from the survey showcased CBL having improved critical thinking, problem solving, teamwork, communication, real-life technical skills, course performance, self-confidence, and the overall learning experience for the students. Additionally, it was found that CBL enhanced concept understanding, application, and induced a deeper conceptual understanding amongst the upper year students much more significantly as opposed to the lower year students.

*Keywords:* CBL; active learning; biotechnology; engineering technology; education

**Sustainability and Ethicality are Peripheral to Students' Software Design** 542–556  
*Siara Isaac, Aditi Kothiyal, Pierluca Borsò and Bryan Ford*

The conceptual design phase is a fascinating moment to observe how a design task is interpreted, as the (often implicit) relative importance students accord to the various requirements and constraints offers a window into the thinking underpinning their designs. Our qualitative study used the think-aloud protocol with 11 third year computer science students working on a software design task to investigate the criteria that students used to guide and evaluate their developing conceptual designs. While the trio of feasibility, economic viability, and consumer desirability are often used in design decisions, our analysis also looked for how aspects of ethics (i.e. ethicality) and sustainability informed students' thinking. We found that considerations of feasibility and consumer desirability dominated students' thinking, while economic constraints were rarely addressed and even less often the economic impact pertaining directly to the software design. Students' consideration of ethicality in terms of data privacy and

accommodations for disability (an explicit criterion in the design task) indicate that many students did not see ethical aspects as sufficiently important to influence their design choices. Sustainability was introduced tangentially in the design task but was absent from students' thinking and design decisions. Our findings suggest that ethicality and sustainability should be explicitly included in the design thinking model taught to students for software design to ensure that they bring these considerations to their professional work and therefore to the next generation of software.

*Keywords:* software design; sustainability; ethics; ethicality; think aloud; human-centred design

### **Community-Student-Faculty Partnership: A Model for Learning via Deep Engagement with the Community**

557–569

*Andrea Hemmerich, Avani K Mehta, Janet Kasperski and Robert Fleisig*

Students benefit from engaging with community partners as part of higher education experiential learning opportunities. As part of one project in the Master of Engineering Design Program's Design Thinking course at McMaster University, students were introduced to several volunteer hospital Patient and Family Advisors (PFAs) who spend several hours per week with the design teams sharing stories about their experiences as patients and/or family members of patients at the hospital. Over the five-week period their interviews with the PFAs help the students frame a specific design challenge, identify design opportunities, test, and get feedback on their ideas. The success of this learning experience within the Design Thinking course can be attributed to the collaborative partnership between hospital PFAs and McMaster students as facilitated by the course instructors. The community-student-faculty partnership model provides students an opportunity to learn about healthcare challenges from the patient – rather than professional – perspective, which also involves mentorship by the PFAs as they help students understand their experience as the primary participants within the healthcare system. Concomitantly, the depth of engagement provides PFAs the opportunity to see the richness of progression of dialogue between the students and “real patients” throughout the students' design process, resulting in inspirational proposals to address their health-related challenges and an appreciation of the students' human-centred design competencies. This collaborative teaching approach supports course learning objectives for students to adopt a human-centred mindset, iterate on prototypes, and learn through feedback. In addition to adding value to students' learning, the project promotes patient-centred healthcare through meaningful involvement of PFAs.

*Keywords:* Students as Partners; Patient and Family Advisors; Experiential learning; Partnership learning communities; Design Thinking; Collaborative Autoethnography

### **Factors Influencing Career Choice, Perceived Discrimination, and Segregation of Foreign-Born Engineering Undergraduates**

570–583

*Rosó Baltà-Salvador, Marta Peña, Noelia Olmedo-Torre and Ruoshi Wang*

The underrepresentation of foreign-born students in engineering degrees is persistent and fosters social disparities in job opportunities and income for future generations. On the one hand, this underrepresentation is related to the fact that foreign-born students choose engineering studies less frequently than native-born students. On the other hand, it is also related to the hostile and discriminatory environment in engineering degrees.

The present research conducted in Spain provides new evidence on differences in students' career choice factors according to their place of birth and the relationship these factors may have with students' academic persistence. In addition, this research explores the exclusion and segregation of foreign-born students and the relationship between segregation and perceived discrimination, providing new data on the specific situations in which segregation and discrimination occur.

The study was carried out based on a cross-sectional survey of 602 engineering students of the Universitat Politècnica de Catalunya-BarcelonaTech. Descriptive and inferential statistical methods were used to analyze the dataset. The results showed significant differences between native-born and foreign-born students among the factors that motivated them to enroll in engineering degrees. Some of the most significant differences were that native-born students felt more motivated than foreign-born students by their skills, aspiring for a high salary, and having a job that made them feel fulfilled. Moreover, a significant association was found between foreign-born students' academic persistence and the factors that motivated them to enroll in engineering, such as family support, getting a satisfying job, and having a high salary. Regarding segregation, native-born students were significantly less likely to interact with students from different origins than foreign-born students. Leisure time and extracurricular activities were the situations in which native-born students interacted the least with students from different origins. Furthermore, in the classrooms where native-born students interacted most with other students, foreign-born students felt most discriminated against. Possible explanations for these findings are discussed in the study.

*Keywords:* career choice; engineering education; inclusion; segregation; underrepresented minorities

### **Analysis of the Ability of ‘Understanding’ in Support of its Measurability**

584–591

*Rayapati Subbarao*

Course Outcomes (COs) are prepared by the faculty of different streams according to the syllabus provided by the University or Board, to which their programs are affiliated to. This involves the selection of appropriate action verbs. While doing so, they are referring to the Bloom's taxonomy table. Recently, it has been modified with the aim of bettering the learning aspect of the students and it has been suggested that ‘Understand’ is not a measurable one. Understanding is nothing but acquiring the knowledge of the system or device or unit one deals with. One cannot apply theoretical concepts and governing equations without acquiring comprehensive knowledge about it. Since many courses deal with the ability of understanding, it must be made clear to the teaching community about its usage. In this context, the present work analyzes by considering different examples pertaining to various core engineering and science disciplines. Initially, all the cognitive levels of bloom's taxonomy are discussed in a general perspective. Subsequently, the levels of learning are discussed with regard to a simple mathematical formula and it is visualized that understanding aspect is measurable. Further, different types of numerical examples or instances of various engineering domains are depicted. Same method is applied to science streams and then with different levels of assessment. Also, special emphasis is given on measuring other abilities that are mentioned in the reference taxonomy table. It is observed that measurement of ‘Understand’ is done before the measurement of either ‘Apply’ or ‘Analyze’ for any numerical problem in case of engineering streams. It must be the same for any other stream or branch of science. Through different short answer questions used in both engineering and non-engineering streams, its measurability is further established. Analysis clearly indicates that it is only a myth that ‘Understand’ is not measurable and that it is not advisable to be used as an action verb, while preparing the learning outcomes. Thus, the present work identifies the appropriateness of ‘Understand’ as a measurable quantity.

*Keywords:* learning outcomes; understand; Bloom's taxonomy; measurable verbs

## Section II

# Contributions in: Critical Thinking, Sustainability, Reflection Ability, Electronics Engineering, COVID-19, Anxiety, Online Learning, PBL, Teamwork, Adaptive Teaching, Multimedia, Problem-Solving Skills, Student Success, Contextual Learning, Motivation, Belonging, Growth Mindset, Peer Assessment, Graduate Students, Blended Learning, and Career Pathway

### Evaluation of Higher Education Students' Critical Thinking Skills on Sustainability

592–603

*Ignacio J. Navarro, José V. Martí and Víctor Yepes*

Construction-related enterprises are acknowledged as one of the key actors responsible for shifting society toward the sustainable future claimed by the recently established Sustainable Development Goals. However, university curricula need to emphasize guaranteeing the acquisition of transversal competencies that are essential for the future management professionals required by this new challenge. Consistent and critical thinking is considered a fundamental skill for education in sustainability. To date, no studies have presented an objective measure of the level of acquisition of such transverse skills in university curricula. This study provides an analytical tool to that end, based on the multi-criteria decision-making technique Analytic Hierarchy Process (AHP). Through sustainability-oriented case studies, students are faced with real managerial decision-making problems. The proposed method allows for the analytic quantification of the consistency of their responses. Such consistency is representative of their critical thinking skills. The proposed tool allows teachers not only to find the consistency of their students' responses but also to understand in which areas of sustainability students lack a clear vision of the problem. This tool is therefore useful for teachers to effectively adapt their syllabi according to their students' knowledge.

*Keywords:* sustainable education; transversal competence; critical thinking; management; consistency

### Relationships Between Reflection Ability and Learning Performance of Junior Electronics Engineering Students

604–611

*Aziz Shekh-Abed and Yinnon Stav-Satuby*

Modernization affects all areas of a company, including procedures, methods, instruments, and data flows, resulting in frequent and brief changes. New approaches and process improvements are essential in engineering projects. The reflection ability has been shown to improve processes by providing advantages for team performance and team invention as an ongoing interaction between thought and action. This quantitative study investigated the interrelationships between reflection ability and learning performance among 30 junior students enrolled in a microelectronics course using the reflection assessment, project assessment, and achievement test. The findings suggested a positive, moderate, and significant correlation between reflection ability and learning performance, with reflection ability significantly predicting performance. Therefore, reflection ability can be an effective instrument for assessing students' learning performance abilities throughout a course.

*Keywords:* reflection ability; learning performance; project-based learning; electrical engineering

### Impact of Online Learning on Engineering Students' Engagement, Anxiety, and Burnout amid the COVID-19 Pandemic

612–626

*Sonja Ivančević, Tatjana Ivanović, Milica Maričić and Mladen Čudanov*

This study proposes a conceptual model that explores the relationship between online learning, student engagement, anxiety, and burnout during the COVID-19 pandemic. Students' attitudes towards online learning are measured using the Online Learning Questionnaire, anxiety is measured using the GAD-7 scale, student engagement using the UWES-17SF scale, and student burnout with the CBI-S scale. Structural equation modelling (SEM) analysis was used to verify the proposed conceptual model on the sample of 584 engineering students of the University of Belgrade, Faculty of Organizational Sciences who are majoring in information systems and technologies, and management and organization sciences. The results show that online learning positively affects student engagement and negatively student anxiety, whereas it only indirectly, through anxiety, negatively impacts student burnout. In addition, anxiety is proven to positively affect student burnout and has no significant effect on student engagement. In conclusion, while it is encouraging that even crisis-induced online learning positively influences student engagement, the confirmed impact of anxiety on student burnout is also valuable as the early identification and treatment of anxiety can significantly contribute to burnout prevention. This should not be neglected since our research has shown that 37.50% of the examined student population experience severe anxiety, while 62.33% and 45.54% of them experience moderate, high, or severe levels of personal and studies-related burnout, respectively.

*Keywords:* anxiety; burnout; COVID-19 pandemic; engagement; online learning; SEM; engineering students

### A Thematic Analysis of Engineering Students' Experiences of Teamwork in Problem-Based Learning

627–642

*Anders Melbye Boelt, Jette Egelund Holgaard and Anette Kolmos*

Changing modes of production and emerging technologies and economies require capable employees equipped with a set of diverse competences. These competences are no longer limited to specific disciplines but include broader emphasis on generic competences applicable across various contexts involving a variety of professions. Consequently, collaboration and teamwork are also two central generic competences in engineering practice and pivotal elements in engineering education. However, collaboration and teamwork competences are often only superficially addressed and moreover, not based on students' experience. This study address engineering students' experience of the constituent parts of teamwork competences in a systematic integrated problem-based learning (PBL) environment and how these can contribute to curriculum development. Conducting a thematic analysis of students' written competence profiles (n = 130) results in the construction of five themes concerning students' teamwork competences: finding complementary competences, establishing teamwork culture, preventing and managing conflicts, awareness of self and others and shared situational awareness. Each theme is illustrated by several components emphasised by students and exemplified by excerpts useful for curriculum development or learning activities supporting development of specific competences. The thematic analysis furthermore exemplifies how generic competences are perceived as enablers of disciplinary problem-solving in teams, and how systematically integrated PBL supports the development of a wide variety of teamwork competences. The article concludes that students are acutely aware of team members and their position in a team while maintaining flexibility enabling potential responses to anticipated or unknown challenges found in the internal or external environment of the team.

*Keywords:* engineering education; PBL; PjBL; generic competences; students' experience of teamwork; competence development

### An Adaptive Methodology for the Improvement of Knowledge Acquisition by a Multimedia Web Tool

643–652

*Gabriel Cerna Pedro Victor, Antoni Perez-Poch, Francisco Alpiste Penalba and Jordi Torner Ribe*

Adaptive learning is a method that personalizes the teaching-learning strategies in accordance with the needs and preferences of each student. This article describes the design, the implementation and the tests of a web application developed with adaptive learning in order to improve student knowledge acquisition and to simplify the teacher's work. The tool uses EventSource technologies combined with heuristic functions to produce a predictive algorithm, which is capable of being adapted to the students in a customized way by presenting the content adjusted according to their cognitive needs. The design is based on the hypothesis

that the acquisition of knowledge can be improved by using a computing application which presents a syllabus to be learned in various forms. In this way, the application determines students' progress within the content of the material, which is classified by branches of knowledge. The tool was applied to one group of students and the data that we obtained was compared with the results of the rest, subject to the usual knowledge transmission system. The results obtained not only improve the academic results, but also enhance the heuristic decision-making about the content to be taught.

*Keywords:* adaptive teaching; predictive algorithm; evaluation; improved learning

### **Impact of Prompting Engineering Undergraduates to Reflect on Their Problem-Solving Skills**

653–667

*Shima Salehi, Karen D. Wang, Michael Flynn and Carl Wieman*

While learning effective problem-solving is an important goal of engineering education, “how should we teach problem-solving to engineering students?” is an ongoing challenge. In our previous works, we identified the main practices involved in solving a novel technical problem involving electrical circuits. Among these practices were reflective practices that regulate the problem-solving process by making more intentional and informed decisions. Expanding on that work, we examine in this study whether we can improve students' problem-solving by prompting their use of reflective practices. The study presented here consists of two experiments. The first experiment was conducted with 16 undergraduate students in a mechanical engineering course. Students were introduced to problem-solving reflective practices and then received prompts to engage in these practice as they worked on their weekly projects. The quality of their problem-solving was evaluated pre- and post-course using interactive electrical circuit problems embedded in an educational simulation. The improved performance in problem solving in the *mechanical engineering context* was observed to transfer and to improve problem-solving *in the context of the electrical circuit problems*. We conducted the second follow-up experiment to confirm that this improvement was the result of the prompted reflection, not simply repeated practice on the test and/or learning about electrical circuits in between the pre- and post-course evaluation. For the second study, 70 undergraduate students were randomly assigned to one of two conditions: practice solving electric circuit problems with prompted-reflection (PR) or receiving extra repeated-practice (RP) solving such problems, but without reflective prompts. Student problem-solving in the PR condition improved nearly twice as much as in the RP condition. Overall, the results of the study show that prompting students to reflect on their problem-solving produces problem-solving benefits greater than repeated practice and these benefits transfer across disciplines.

*Keywords:* problem-solving; reflective practices; reflective prompts; repeated practices

### **Institutional Characteristics and Engineering Student Non-Cognitive and Affective (NCA) Profiles**

668–684

*Justin C. Major, Matthew Scheidt, Allison Godwin, Heather Perkins, Sanga Kim, Brian Self, John Chen and Edward Berger*

In our prior work, a cluster analysis ( $n = 2,339$ ) identified four groups of engineering undergraduates' non-cognitive and affective (NCA) factors from a list of 28 dimensions such as belongingness, engineering identity, self-control, and perceptions of faculty caring. We found clusters of students that generally contained favorable student success characteristics (high belonging, high engineering identity, high motivation, and others), as well as those that were characterized by less favorable characteristics for student success (low belonging, low perception of faculty caring, and others). Higher education institutions have varying missions and profiles, and they serve different student populations. We hypothesize that as institutional characteristics are related to specific NCA (institutional characteristics may affect belongingness, stress support, perceptions of faculty caring, or other constructs from our NCA-based clusters), they may also be related to cluster membership. To test our hypothesis, we merged our dataset with institutional data from the Integrated Postsecondary Education Data System (IPEDS), engineering program enrollment data from the American Society for Engineering Education (ASEE) Engineering Data Management System (EDMS), and financial data from the U.S. Census Bureau. The final data for this analysis consisted of  $n = 1,252$  responses across 14 U.S. institutions. We used multinomial logistic regression to predict cluster membership as a function of both individual and institutional characteristics. We found that institutional characteristics correlate to cluster membership in important ways: students at large and/or and doctoral granting institutions have decreased odds of being in a generally positive cluster containing favorable student success characteristics, while enrollment at guaranteed tuition institutions increases these odds. These results elevate the role of institutional culture and its alignment to student characteristics as a key component of successful student outcomes. These results, when considered as a question of student-institution alignment, offer opportunities to rethink student academic and social support structures that encourage growth in specific NCA factors. In turn, this growth may support expanded engineering student success.

*Keywords:* institution type; non-cognitive and affective factors; affective theories; academic support; student success

### **Development of Adaptive Expertise in Engineering Undergraduates through Contextual Computer Aided Design Modeling Activities**

685–702

*Elif Ozturk, Michael D. Johnson, Bugrahan Yalvac and Xiaobo Peng*

To survive and thrive in today's fast-changing workplace, engineers will need to become adaptive experts. Undergraduate education can play a critical role in improving engineering students' adaptive skills that are important for their future productivity. This education must integrate practice and mastery of Adaptive Expertise (AE) dimensions in the engineering curriculum. In this study we investigated the role of various factors on the undergraduate engineering students' manifestation of AE through contextual Computer-Aided Design (CAD) exercises. A total of 390 students from two universities were asked to model either a stylized or familiar component that they brought from home as a contextual exercise. In both cases, we conducted pre and post interviews with the students to capture how they approached their tasks and overcame any challenges. Effects of the contextualized activity on students' AE characteristics were investigated. In addition, utilizing the Adaptive Expertise Survey (AES), we collected data from over 600 participants spanning students over three years from two institutions as well as industry professionals. We found that the overall manifestation of AE during CAD exercises was significantly correlated with overall total AES scores. Participants' increased experience and education were shown to be associated with their increased AE captured through both the survey administrations and interview sessions. Contextual CAD modeling exercises had an effect on AE manifestations. Our findings provide insights into the research conducted to enhance CAD instruction. We report that multiple perspectives, goals and beliefs, and metacognitive skills are indicators of developing AE and that educators should consider promoting those skills in CAD education.

*Keywords:* CAD; adaptive expertise; contextual learning

### **Impact of a Voluntary Extracurricular Research Program on Engineering Students' Sense of Belonging: An Exploratory Case Study**

703–718

*Homero Murzi, Jose Torero, Kevin Sevilla and Joe Gattas*

In this paper, we present results of our exploratory study to explain students' experiences with the Icarus program. The program's goal was to provide students with a different space to develop sense of belonging. The research design is an exploratory case study. Data were collected quantitatively using a survey and qualitatively using semi-structured interviews. Results showed that students' primary motivation to join the Icarus program was to apply theory from class into real-world engineering problems and to work and engage with peers. In addition, students' experiences with Icarus aligned with the constructs desired for promoting sense of belonging. The program helped solve one of the issues in the School, an improvement in academics and student interactions. Students' experience with the program was positive, and they reported how it improved issues related to their academic program, their relationships with mentors, and their perceptions of inclusion.

*Keywords:* sense of belonging; motivation; extracurricular program; voluntary research

*Fredericka Brown, Katherine E. Pierce, Trina Fletcher, Sung Eun Park and Kelly J. Cross*

Multiple factors influence faculty instructional practices and strategies in engineering. Effective strategies for improving instructional practices are correlated to the belief of the individual faculty. While substantial research has been done on how faculty and their instructional practices can make a positive difference in student achievement, less research has been done on how faculty's mindset drives instructional practices. This study aims to fill this gap. This study sought to answer two research questions: (1) What is the continuous fixed through growth mindset of engineering faculty with respect to faculty demographics? (2) Is there a difference in self-reported instructional practice with respect to faculty mindset and faculty demographics? In Fall of 2019, we used an online survey to collect survey responses from 105 engineering faculty from 14 different engineering colleges at Carnegie classified as Doctoral/Professional universities. The survey instrument included two scales with existing validity evidence: the Dweck Mindset (DMI) and the Postsecondary Instructional Practices Survey (PIPS). The analysis generated three key results: (1) engineering faculty in the sample did not score along the mindset spectrum, most fell in the middle of the spectrum and were categorized as incremental; (2) there was a statistically significant difference in engineering faculty mindset that varied by faculty demographics including gender, ranking, and tenure status; and (3) student-content engagement and student-student engagement were found to be the most discriminant teaching practices. Our study demonstrates strong correlation between the mindset of engineering faculty and instructional practices, as well as how that correlation varies by faculty demographics. Our results suggest faculty mindset is a malleable construct that can directly affect teaching practices leading to better teaching and learning in engineering. Furthermore, our study supports the implementation of training to ensure tenured faculty are comfortable with a growth mindset as well as the need to continue to increase the diversity of engineering faculty.

*Keywords:* engineering faculty; growth mindset; instructional practices; teacher authenticity

**Peer Assessment for Engineering Design Education: An Exploratory Study**

732–742

*Hyunkyung Lee, Daeun Jung and Hyungjin Kim*

This study investigated the influence of engineering design classes with peer assessment on learning outcomes and the learners' and instructor's perceptions of peer assessment. For this purpose, 39 college engineering students in the engineering design class at a university in Korea were asked to conduct peer assessments twice. As a result, engineering design classes with peer assessment significantly improved learners' computational thinking, creative problem-solving, and collective efficacy. The learners and the instructor recognized that peer assessment can help develop problem-solving skills and cultivate a mindset as an engineer in the engineering design. However, they commonly noted the problem of insufficient time for assessment activities during class. Some students also doubted their own and their peers' ability as assessors. This study contributed to expanding the understanding of the role of peer assessment in the context of engineering design education.

*Keywords:* peer assessment; engineering design education; physical computing; computational thinking; creative problem solving, collective efficacy

**Current Trends in Blended and Online Learning**

743–760

*Mahyar Mohammadi, Maria Paasivaara and Jussi Kasurinen*

Blended Learning (BL) combines the advantages of both in-person and online learning while allowing students to affect their learning schedules and take responsibility. The capabilities of online education took worldwide interest during the COVID-19 pandemic, with the need to better understand online education's impact on educational achievements and how technical environments could provide learning experiences to replace face-to-face sessions at the campus. We examine the trends towards online learning on the recently published articles during the COVID-19 pandemic, comparing them to a learning survey conducted in the European Union in 2021. The study's objective is to identify the current trends and the effect of the COVID-19 pandemic on online education. This paper compares our findings from a systematic literature review against the trends observed from qualitative survey data collected from six European countries. Our mapping study identified several trends, such as that long-distance education had become a long-term strategy in higher education compared to the pre-COVID-19 era and that fully online education can be very exhausting for students, causing retention problems with those who need more skills for independent studies. The BL methods engage students and allow them to design their learning schedules, and after COVID-19, these methods are becoming long-term strategies for education. However, these approaches also require skills in the course design to ensure that other aspects and needs, such as social inclusiveness to motivate students, are sufficiently addressed due to the need for classroom interactions and peer support from shared campus experiences.

*Keywords:* blended learning; online learning; engineering education; software engineering

**Women Engineering Graduate Students Changing Professional Interests in Academia**

761–773

*Kerry L. Meyers, Victoria Goodrich and Siqing Wei*

The disproportionately low number of women in engineering faculty roles is concerning to academic administrators, faculty, and students. Prior studies have focused on engineering identity but not on how the interests of women engineering graduate students may change throughout their program progression. The research reported here focuses on the differences in the professional plans of women engineering graduate students early in their Ph.D. programs as compared to those near completion of their graduate studies. A mixed method study was conducted using survey and focus groups at a medium-sized, Midwestern, private institution during the summer 2021. A survey was sent to about 600 engineering PhD students (both male and female) with analysis primarily utilizing Kruskal-Wallis H tests. Additionally, focus groups of four to six students were conducted based on program progression and gender to better understand the quantitative findings. Survey responses were analyzed by program progression, gender, and international status. Results show that women engineering Ph.D. students' interest in an academic career decreases as they progress through their graduate studies. There are also differences between domestic and international Ph.D. students in terms of their professional interests which is entangled with their legal and immigration status. It is recommended that engineering graduate programs offer formal professional discernment opportunities for 2nd year Ph.D. students, both male and female, to help them to recognize the opportunities available to them upon program completion. And additionally, for Diversity, Equity and Inclusion efforts be expanded to consider the needs of graduate students in retention.

*Keywords:* Women; Graduate Student; Career Pathway; Professional Discernment