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Special Issue

Good Practices for Emergency Situations and Remote Regions – Part 2

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Responsive Educational Transformations During Emergency Situations: Collaborative Autoethnography Applied to the Engineering Classroom 288–298
Lisa B. Bosman, Ebisa Wollega and Usman Naeem

In general, higher education has been slow to innovate in comparison to industry and many for-profit organizations. This is primarily because non-profit higher education institutions are highly regulated, extremely bureaucratic, and do not always act strategically concerning finances (given the non-profit status). However, COVID-19 has forced engineering educators to innovate and transform the learning experience within a short time period; yet, because COVID-19 is a recent phenomenon, there is limited literature highlighting best teaching practices for a variety of teaching formats such as HyFlex Learning, Virtual Synchronous Learning, and Blended Learning. The purpose of this study is to offer readers a collaborative autoethnographic approach summarizing the researchers' experience teaching engineering coursework in each of these learning environments. Autoethnography employs self-reflection to recognize, explore, and appreciate personal experiences and anecdotal evidence and allow for a deeper understanding across individual perspectives to contribute to a wider explanation of a phenomenon. The data was collected from three different professors at three different universities: (1) Public R1 University (Predominately White) in the Midwest United States (HyFlex Learning); (2) Hispanic Serving Institution in the Southwest United States – (Virtual Synchronous Learning); and (3) a Russell Group University in the United Kingdom – (Blended Learning). The data collection applied a structured approach, where each professor reflected upon and documented their experiences teaching during COVID-19 while considering: (1) background and context, (2) teaching and learning changes implemented, and (3) lessons learned. The study concludes with a table of best teaching practices and recommendations for engineering educators.

Keywords: autoethnography; pandemic; engineering; COVID-19; higher education; undergraduate

Distance Learning: Should We Go Interactive At Any Cost? 299–309
Ivan Pinčjer, Ivana Tomić, Savka Adamović and Nada Miketić

The need for successful self-directed distance learning is not a new construct in education. However, the circumstances surrounding the emergence of the COVID-19 pandemic have emphasized the weaknesses of distance learning. The transition of students to distance learning has become inevitable. In current times, educators' task is to ensure the same quality of distance learning as in-person learning. The present paper contributes to our understanding of this task by examining good practice recommendations in instructional design. The experiment's focus is the effectiveness of interactive 3D learning tools in engineering studies depending on the level of study, i.e., prior knowledge of the students. Two separate experiments were conducted with 138 first-year and final-year university students studying the same material in three different instructional designs: interactive animation, continuous video and images. All three groups received textual information through identical narration. The results showed statistical significance among the lower prior knowledge students regarding knowledge transfer issues, while there was no statistically significant difference among the respondents with higher prior knowledge. These results suggest that substantial financial resources and time can be saved in preparing materials for various degrees in higher education.

Keywords: distance education; instructional design; technology-enhanced learning; *prior knowledge*

Can In-Home Laboratories Foster Learning, Self-Efficacy, and Motivation During the COVID-19 Pandemic? – A Case Study in Two Engineering Programs 310–321
Jonathan Álvarez Ariza

The COVID-19 pandemic has represented a challenge for higher education in terms to provide quality education despite the lockdown periods, the transformation of the in-person classes to virtual classes, and the demotivation and anxiety that are experimented by the students. Because the basis of engineering is the experimentation through hands-on activities and learning by doing, the lockdown periods and the temporary suspension of the in-person classes and laboratories have meant a problem for educators that try to teach and motivate the students despite the situation. In this context, this study presents an educational methodology based on Problem-Based Learning (PBL) and in-home laboratories in engineering. The methodology was carried out in two phases during 2020, in the academic programs of Industrial Engineering and Technology in Electronics with (n = 44) students. The in-home laboratories were sent to the students as part of "kits" with the devices needed in each subject. Besides, due

to the difficulties in monitoring the learning process, the students made videos and blogs as a strategy to reinforce their learning and evidence the progress in the courses. The outcomes of the methodology show mainly the following points: (1) An improvement of the academic performance and learning of the students in the courses. (2) A positive influence of the usage of in-home laboratories in motivation, self-efficacy, and reduction of anxiety. (3) Positive correlations between the usage of in-home laboratories, the blogs and videos, and the teacher's feedback for learning, motivation, and self-efficacy. Thus, these results evidence that other alternatives that gather the cognitive and affective learning domains can emerge from engineering to deal with the educational problems produced by the crisis periods. Although the methodology and the lessons learned in this study are applied to the pandemic period, they can be extended in engineering education to the post-pandemic period.

Keywords: in-home laboratories; problem-based learning; emergency remote teaching; emergency remote learning; self-efficacy; engineering education, COVID-19

Teaching Computer Science and Computer Engineering During COVID-19 Lockdown at the Pakistani Universities 322–334
Muhammad Khalid Shaikh, Tahseen A. Jilani and Kamran Ahsan

A study is conducted with 368 teachers teaching various undergraduate Computer Science and Computer Engineering courses in an under-developed country – Pakistan, during the COVID-19 pandemic. A teaching model is presented in this research, suggesting that the grit had played an important role in technology adoption for online teaching during the COVID-19. It is found that although the absence of technological support such as high speed Internet and consistent, robust and useful LMS, teachers were still adopting and using technologies such as Google Classroom, Zoom and WhatsApp groups for teaching the students in real-time or through recorded videos. This behavior is explained by the teacher's grit that has also motivated the adoption of online teaching related technologies. The lack of technology such as LMS does affect the user satisfaction, however, it didn't affect the usage behavior of the adoption and use of technology. The initial research model had components from non-cognitive learner characteristics, and from various popular technology usage and acceptance models such as an Information System success model, and Unified Theory of Acceptance and Use of Technology. A quantitative questionnaire survey is conducted to assess the proposed research model. The resultant research model had components only from non-cognitive learner characteristics and Unified Theory of Acceptance and Use of Technology model. The data is analyzed using SEM PLS, K-means clustering and Decision Tree classification method.

Keywords: perseverance; technology; acceptance; COVID-19; under-developed countries

Impact of COVID-19 on the Teaching and Learning of a Graphic Engineering Course 335–349
Rosó Baltà-Salvador, Noelia Olmedo-Torre, Luis Eduardo Mujica and Marta Peña

The current situation derived from the COVID-19 crisis is generating unprecedented challenges throughout the educational community, although higher education institutions have demonstrated their ability to adapt very quickly and with great flexibility to the crisis. Since the beginning of the pandemic, students are experiencing new learning environments and employing a broad set of resources whose impact on their overall learning has yet to be discovered and is being investigated. There are also many unknowns to solve about how the lockdown has affected them.

This research provides new evidences on this unprecedented phenomenon about aspects related to their learning and their effect on confinement in a Graphic Engineering subject through a cross-sectional survey conducted with a students' group (n = 264) during the pandemic period using triangulation of data analysis. A quantitative comparison of the final marks of the students has also been made between the emergency situation and the one before the confinement.

The results show a clear and direct relationship between academic performance of the students in pandemic period and variables such as the degree of attention, the time spent on assigned tasks and the conditions of the workspace. The best evaluated training activities are the project and the exercise videos. In general, women are more satisfied with their academic performance and evaluate the practices more positively than men. Although the responses of women have been found to have somewhat more variability than those of men, no meaningful results can be extracted. Final marks and the marks of the autonomous learning competence of the subject increased slightly at the beginning of the pandemic period compared to previous periods, but in the following quarter of confinement the marks were maintained or even decreased with respect to the pre-pandemic period. Finally, the study identifies best practices that will be of value for distance teaching and engineering education beyond the pandemic situation.

Keywords: engineering education; graphic engineering; distance learning; COVID-19 pandemic; academic development

Exploring the Impact of the COVID-19 Pandemic on the Lives of Engineering Students at San José State University, USA 350–364
Patricia Ryaby Backer and Maria Chierichetti

In 2020, the College of Engineering at San José State University (SJSU) conducted a comprehensive analysis of the impact of COVID 19 on student learning and achievement. The purpose of this study is to assess the impact of COVID 19 on engineering students at SJSU. This study was a combination of a quantitative survey and a qualitative study. In Part 1, we surveyed all engineering students about their experiences after the move to 100% online instruction in March 2020. In Part 2, we interviewed 40 students to get more insight into their experiences during the move to online in Spring 2020. Overall, 993 students participated in the survey, 64% male and 34.5% female. The students reported feeling worse or much worse in several areas including time management (58.6%), ability to socialize with fellow students (86.1%), ability to socialize with friends (77.7%), and their overall psychological well-being (65.3%). Also, 79% of students reported either a moderate or a great deal of stress related to the shelter in place. This finding of increased stress was also emphasized in our interviews with the students. It is troubling since it indicates a declining mental well-being of students. SJSU engineering students were pessimistic about the next few months, Fall 2020, and their long term plans. We were able to get valuable information regarding effective methods of online teaching and areas where the students struggle the most. We will use this information to improve online teaching and student support in the upcoming semesters.

Keywords: COVID-19; online teaching; student wellbeing; student survey; interviews

Undergraduate Student Opinions on Emergency Remote Teaching during COVID-19 Pandemic. A Case Study 365–375
Gábor Indra Hidalgo, Fermín Sánchez-Carracedo and Daniel Romero-Portillo

The COVID-19 pandemic has shaken education around the globe due to the sudden closure of schools and universities. Undergraduate students have suffered the confinement while continuing their courses by Emergency Remote Teaching (ERT) from home. The objective of this research is to determine the opinions on ERT versus face-to-face classes of students enrolled in the Bachelor's Degree of Industrial Technology Engineering at the Universitat Politècnica de Catalunya-BarcelonaTech (Spain). An end-of-semester online survey was sent to all the students enrolled in the 19/20 spring Chemistry subject. The students' comments were analyzed using the constant comparison method. Six categories were created using an inductive method and student responses were classified according to these categories. In general, the results show that these students prefer face-to-face classes rather than the methodology used during the ERT. They also prefer classes via video-conference if remote teaching is required. There is a diminished perception of socialization with both instructors and peers. Some students positively value that their autonomous learning has improved, and would like to continue accessing the material online even if face-to-face classes were resumed. They also state that completing weekly exercises helped them stay connected to the subject and to sustain learning, and thank instructors for the efforts made to adapt the methodology to the exceptional situation. The information gathered will enable teaching staff to design a remote teaching methodology that meets students' needs better than ERT, should further confinement be required by the authorities due to health emergencies or other types of catastrophic events.

Keywords: Emergency Remote Teaching; COVID-19, opinions; student survey; constant comparative method; inductive method

Leanne A. Grieves, James Mckendry, Nasim Muhammad and Seshasai Srinivasan

In light of Covid-19, McMaster University abruptly transitioned all classes to an online format in Winter 2020, with online classes continuing through the Winter 2021 term. To improve our existing technological framework for the delivery of online courses, we surveyed undergraduate students in McMaster University's engineering program to assess their online learning preferences and their experience of the transition from in-class to strictly online learning. We identified student preferences for educational video type, number, duration and identified barriers to an online learning environment. In addition to outlining the students' perspective, we present our findings in the context of the students' learning by contrasting student learning in the online environment with the learning of earlier cohorts in the in-person environment (i.e., before the pandemic). We assess learning via student performance in exams and assignments for each course. After considering the student's perspective and learning outcomes, we provide recommendations for an optimal content delivery methodology in an online learning environment.

Keywords: active learning; constructivist theory of learning; Covid-19; education; online learning

Challenges and Opportunities for Higher Engineering Education During the COVID-19 Pandemic

393–407

Aziz Shekh-Abed and Nael Barakat

The pandemic caused by COVID-19 had a profound impact on engineering education challenging both educators and students to innovatively continue the learning process and unveiling many of the issues hindering education systems' resilience. To explore the challenges to engineering education which were imposed by the COVID-19 pandemic, responses to the challenges, and the underlying reasons. The hypothesis is that these challenges overlaps with challenges to sudden change of instruction to become remote while belonging to four categories: Access and compatibility, Remote and hybrid assessment, Lab and experiential learning delivery, and interpersonal relations and support societies. The goal is to use the outcomes to propose themes for consideration in building a sustainable and resilient engineering education system.

Students' responses to a questionnaire were analyzed utilizing quantitative and qualitative tools. 124 engineering students volunteered to participate in the questionnaire. Results were coded and categorized to allow studying their interrelations. Challenges to engineering education caused by the COVID-19 pandemic were found to belong to three categories (performance, adaptation, and accessibility-and-compatibility). These categories are interrelated in a significant moderate positive correlation. Also, socio-economic status of students, life experiences and maturity levels, as well as availability of resources by location or other means, play a significant role in improving students' adaptation to rapid changes in the education process, and consequently affects their academic performance. Education systems aiming at becoming resilient can start by improved infrastructure and training programs related to advanced technology as well as enhancing levels of equity of access for their students.

Keywords: learning environment; engineering education during the pandemic; resilient education systems

Online Learning Perceptions amid COVID-19 Pandemic: The Engineering Undergraduates' Perspective

408–420

Meltem Eryilmaz, Guler Kalem, Hurevren Kilic, Guzin Tirkes, Damla Topalli, Cigdem Turhan, Burcu Alakus and Ali Yazici

The COVID-19 pandemic caused face-to-face education in just about all universities worldwide to shift to online education. For most students, this educational model was a compulsory first experience. In this study, the survey results are analyzed and discussed related to a group of students in the Engineering Faculty of a university in Turkey regarding their online education perceptions. Briefly summarized, the findings of the study indicate that: (a) most of the students still prefer face-to-face learning, which is also favored if accompanied by distance learning; (b) the concentration level of the students has dropped due to the concerns about the COVID-19 pandemic which affects their learning negatively; and (c) around half of the students participating in the study feel that the online exams conducted without a secure exam software, is considered unsafe. Additionally, the study's results were further extended to evaluate the questionnaire results and reported along with the suggestions of necessary actions in emergency online learning (EOL).

Keywords: COVID-19; online learning; emergency online learning (EOL); distance education

Evaluating Technological Acceptance of Virtual Learning Environments (VLE) in an Emergency Remote Situation

421–436

Luis Magdiel Oliva-Córdova, Antonio Garcia-Cabot, Sonia Alejandra Recinos-Fernández, Maylin Suleny Bojórquez-Roque and Héctor R. Amado-Salvatierra

The digital acceleration that took place in the middle of COVID-19 pandemic made the universities implement strategies to face the challenges brought about by the irruption of non-face-to-face education. In Guatemala, the universities opted for online, virtual, and distance learning methodologies where in a short time they organized themselves to build a learning system to solve the emergency, which in the beginning was considered to last a few weeks; however, the digital learning ecosystems were consolidated, as time went by, and to the extent that all agents of the educational community were involved in the process. The higher education institutions implemented strategies to continue providing instruction, and the academic year ended with a full distance education system, using virtual educational platforms and networked communities to optimize time and resources that are transforming university management worldwide. This work presents a theoretical model that assessed teachers' technological acceptance of virtual learning environments (VLE) in an emergency remote situation. The study was prepared from the perspective of 345 teachers from different faculties in a higher education institution. The work is complemented with recommendations and best practices from the experience with a special focus on the use of learning analytics techniques in virtual engineering education.

Keywords: virtual learning environments; engineering education; technology acceptance; learning analytics

Hybrid PBL Teaching Practice under COVID-19 Impact – A Case Study

437–451

Shi-Jer Lou, Chuang-Yeh Huang, Yuh-Ming Cheng and Chih-Chao Chung

In this paper, the authors describe the development of a hybrid problem-based learning model for teaching during the COVID-19 pandemic, explores its impact on student learning effectiveness, and collects feedback from teachers on the teaching site. This study adopted experimental teaching with 30 students in the elective course of "Technology Application and Practice" of a university of science and technology as the research subjects. The hybrid PBL teaching model was applied and a 9-week "SDGs (Sustainable Development Goals, SDGs) App Creative Design Project" was implemented to collect qualitative and quantitative data for inductive analysis. The results of this study indicate that, in order to respond to students' learning inconvenience and the panic caused by COVID-19, "student-centered" hybrid PBL teaching should be implemented, and it is also necessary to provide students with care in learning and life. Furthermore, the real-time and functionality of the Line platform should be utilized for students' interactions with teachers and peer exchanges during the hybrid PBL courses. In summary, the innovative hybrid PBL course implementation method, as proposed by this study, has been affirmed by most students, and has shown positive and significant improvements in learning content and skills, teamwork, and task achievement. Finally, advice regarding hybrid PBL course teaching is put forward as a reference for implementation and application on the teaching site.

Keywords: hybrid PBL; COVID-19; SDGs; education reform; teaching practice

Section II

Contributions in: Mechatronics, Multidisciplinary Design, Supply Chain, Industry 4.0, Student Research, Database Management, Teacher Experiences, STEM, Teachers Perceptions, Design Thinking, Empathy, Engineering Identity, PBL, Case-Based Learning, Biotechnology, 3D Printing Course, Creativity

Applying Graphical Representation Method in Teaching Mechatronics Problems in Industrial Automation to Undergraduates – A Case Study

452–465

Julio Garrido, David Santos, Diego Silva and Enrique Riveiro

Industrial automation engineers need a detailed knowledge of the mechanical system of the machines when they program and implement complex motion control functionalities on machines. However, there are no information standards to support the conceptual design of a new machine with all relevant data required for both mechanical and motion control views. As an academic consequence, programming exercises and lessons lose linkage with the mechanical specification, and the experience of students is more focused on the automation perspective. Therefore, the authors have proposed a new intermediate information representation system between mechanics and logic representations: “Mechanical and Motion Control Schematics” or MMCS, which may serve as a support for the teaching of advanced programming of motion control functionalities of machines. The paper addresses the hypothesis of whether the use of MMCS improves the communication and understanding of advanced concepts of movements when compared to mechanical drawings. To assess its usefulness, an experiment presented in this article was designed and performed. Two groups of students carried out a timed test with identical exercises varying only the mechanical documentation used. One group used the standard mechanical drawings as a reference, and the other group used the mechatronic drawings presented in this article. The experiment results show that MMCS provides benefits in reducing time and a better understanding and strengthening of advanced concepts of motion control.

Keywords: academic support; engineering education; industrial automation engineering; mechatronics; multidisciplinary design; practice test

Current Trends in Supply Chain Training Programs in the Context of Industry 4.0 Technologies

466–481

Lei Xie, Malini Natarajarathinam, Michael D. Johnson and Shaoping Qiu

This systematic literature review attempts to identify current training and development (T&D) programs that have adopted Industry 4.0 technologies in the field of supply chain. It further endeavors to identify knowledge gaps and provide future research avenues to researchers. In this paper, we systematically reviewed the extant literature and included a total of 48 articles. The reviewed training and development programs are overall industry-need driven and focus mostly on training employees to apply new technology in the Industry 4.0 environment. However, the performance evaluation of the training and development programs are generally lacking. We also found that with a general rising trend in research interest about Industry 4.0 in supply chain workforce T&D around the globe, some regions such as Latin America are not actively engaged in this endeavor. We suggest supply chain organizations develop employees’ technical skills and invest in training to embrace the change that Industry 4.0 has generated. Future researchers should consider filling the knowledge gaps this research identified on future workforce training and development in the wake of Industry 4.0.

Keywords: Industry 4.0; supply chain management; workforce; training and development

Literature Searching/Compiling/Understanding for Support of Student Research/Projects: A Dedicated Course Approach

482–490

Thomas K. Gaylord and Bette M. Finn

Searching, compiling, understanding, and explaining the literature relative to one’s research or project represents an essential 21st century skill for students. The innovation in the present work is that the *full range* of these diverse topics can be integrated and team taught, in a single unified course format. There is widespread awareness that the rapid advances in technology have greatly accelerated fundamental progress in science, engineering, and medicine as well as in the entrepreneurial development in these fields. Simultaneously, there have been, perhaps less publicized, advances in information science, database technology, literature searching tools, data compilation tools, and data sharing tools. To be competitive, students need to learn about and to incorporate these powerful tools into their research and engineering project work while they are in school and after graduation. Lessons learned in developing a productive academic research laboratory (Optics Laboratory at Georgia Tech) were used to formulate an inclusive suite of the needed topics and to introduce these via a course for undergraduate students to be team taught by an engineering professor and several librarians. After five offerings, this course has earned permanent listing. The resulting 2-credit hour elective “Research Methods” course has gotten high course evaluations. The course has enrolled not only the intended undergraduate students, but also has attracted graduate students, post-doctoral researchers, and faculty as well.

Keywords: Literature searching; database management; research methods; team teaching; educational software

Primary and Middle School Teacher Experiences of Integrated STEM Education in China: Challenges and Opportunities

491–504

Qianru Lyu, Feng-Kuang Chiang and James Davis

Integrated STEM education is a novel and at times controversial approach to teaching, particularly in school systems such as China where there strong are traditions of teacher-directed learning. Implementation of integrated STEM education is influenced by teachers’ experiences of established and new teaching practices that shape what teachers may identify as challenges and opportunities. Our aim in this study is to address the need for understanding teacher experiences with integrated STEM education in primary and middle school contexts in Beijing, China. We adopt a methodology informed by grounded theory to explore and interpret the ideas generated by 12 teachers of integrated STEM. Our findings indicate both resonance and difference with international experiences in terms of challenges that are experienced, and the complexities of issues related to teaching practices. The interplay between integrated STEM and mathematics education is an important feature of this study, which opens a broader issue about teacher and student understandings of engagement. The study also addresses teacher professional development and professional learning to support the implementation of integrated STEM education in Chinese schools. This study highlights issues with: engaging Chinese students in integrated STEM lessons; resonance and difference between Chinese and international teachers; and, contextualized professional development. Future research should address the diversity of education in China, and access to student voice in relation to integrated STEM education.

Keywords: experiences; China; integrated STEM; mathematics; students; teachers

Elementary Teachers’ Perceptions of Engineering Education: A Survey Study in Taiwan

505–511

Pao-Nan Chou and Wei-Fan Chen

This study investigated elementary teachers’ perceptions of engineering education using a self-developed assessment tool (Science Teachers’ Views on Engineering in Elementary School Questionnaire). Prior to the study, exploratory factor analysis and reliability

testing involving 117 elementary teachers were performed to evaluate the validity and reliability of the questionnaire. Through snowball sampling, 202 certified elementary science teachers completed the survey. The results indicated a medium level of overall understanding among elementary science teachers regarding engineering education. Teachers perceived a lack of engineering expertise and had little experience in teaching engineering. Although schools did not actively support teachers' engineering teaching or STEM education activities, teachers had high expectations of higher education institutions to provide engineering education training and of education authorities to offer a specific framework for engineering teaching in the science curriculum. Moreover, teachers' college majors influenced their perspectives on engineering expertise and engineering teaching as well as their overall understanding of engineering education.

Keywords: engineering in elementary school; K–5 science curriculum; engineering instruction

Creating Space for Empathy: Perspectives on Challenges of Teaching Design Thinking to Future Engineers

512–524

Diana Bairaktarova and Donald Plumlee

Design thinking has generated widespread momentum today in several areas where new ideas transform our everyday lives. Engineering design schools have created and sustained a new discipline that uses the designer's sensitivity and design methods to create customer value, experience, and market opportunity. Guided by current best practices in design education we created a design thinking course and offered students content adapted from the most well-established design programs. This paper presents instructional and administrative perspectives, challenges faced, and lessons learned on adaptive design and implementation of the design thinking course within a resource-constrained environment in a small engineering program.

Keywords: design thinking; design education; empathy; engineering

Students' Views on Sources of Engineering Identity Development in a Collaborative PBL Environment

525–542

Juebei Chen, Xiangyun Du and Anette Kolmos

This study examines the interplay between individuals' subjective actions and interactions with the collaborative PBL (Project/problem-Based Learning) environment for engineering identity development in order to capture engineering students' perception of what is important for their professional identity development in a PBL curriculum. A conceptual understanding of sources from internal and external domains was reported. Internal sources included students' interest in specific engineering topics and interdisciplinary projects, intention to promote changes in society, and belief in their engineering competences. External sources in the PBL included opportunities to work on real-life problems and gain work-related experience, allowing them to explore how engineers work, understand engineers' responsibilities, and interact with members from engineering communities. The outcomes of this study highlight the ongoing interplay between internal and external sources, indicating that internal sources offer support for individual choices of professional socialization experience, which are also related to relational sources, contextual sources, and other external sources. Suggestions for future PBL curriculum design propose that engineering educators provide a learning environment that supports students' better use of multiple sources for development of their engineering identity.

Keywords: engineering identity; teamwork; project-based learning; internal sources; external sources

Effect of Case-Based Learning (CBL) on Student Performance in Engineering Biotechnology Education

543–548

Faiez Alani, Fei Geng, Mae Toribio and Rehmat Grewal

Case-based learning is a method that has been used increasingly in a variety of disciplines. However, in the engineering technology education, this method is still underutilized. The goal of this study was to evaluate the effect of case-based learning in the performance of engineering technology students. Students enrolled in an undergraduate biotechnology course answered an anonymous survey about the effects of CBL on different factors that are linked to improving their performance. The results demonstrate that CBL had a positive effect on the students' learning experience, concept understanding, and deep understanding for the course which contributed to the effectiveness of CBL in improving the students' performance. Furthermore, this study found that having more cases reviewed per term increased the student performance based on their final marks on the course, clearly indicating the positive impact of CBL on student performance.

Keywords: CBL; active learning; pedagogical research; student performance; engineering biotechnology

Development and Assessment of a 3D Printing Course for Technical High School Students

549–563

Yun-Hsuan Chu, Chih-Chao Chung, Ru-Chu Shih and Shi-Jer Lou

The purpose of this study is to use the 5E model (Engagement, Exploration, Explanation, Elaboration, Evaluation; 5E) to develop a 3D printing course for technical high schools, and to explore the impact of this model on students' learning effectiveness. This study invited five experts to conduct focus interviews to explore the development of student-centered 3D printing courses in the 5E model, and jointly developed a 5E 3D Printing Course and a learning effectiveness scale. In addition, 39 students majoring in mechanical engineering from a technical high school in southern Taiwan were selected as subjects to conduct experimental teaching, and the learning effectiveness of the students was investigated by questionnaire survey. This study proposed a 5E 3D printing course, including: (1) course objective planning, (2) machine elements and design application, (3) topic setting and revision, (4) mechanical parts drawing and combination simulation, (5) 3D printing practices, (6) presentation and sharing of results, and summarization of the key points of teaching at each stage. After 18 weeks of experimental teaching, significant positive feedback was obtained from most students, indicating that this course is conducive to the improvement of their learning effectiveness. According to the conclusions, the 5E 3D printing teaching model was developed, and the 6-stage curriculum planning and implementation suggestions were put forward for students and teachers, in order to provide a reference for teachers to participate in 3D printing courses in the future.

Keywords: 5E model; 3D printing course; high school students; education reform

Investigating How Early-Career Engineering Faculty Perceive the Role Creativity Should Play in Engineering Education

564–580

Hao He, Johannes Strobel, Suzanne Burgoyne, Joshua Saboorizadeh, Heather K. Hunt and Ferris Michael Pfeiffer

Creativity is critical to engineering. This study aimed to understand engineering faculty members' perceptions of creativity and its relationship with engineering, their teaching philosophies, how they perceived their own and their students' creativity, and how their teaching philosophies affected their beliefs of incorporating creativity into engineering education. To accomplish our goal, we interviewed ten engineering faculty members and conducted a thematic analysis. The results indicated that the faculty members loved teaching and sharing knowledge, that they inherited their teaching skills from their teachers, or they learned them from colleagues or training camps, and that they enjoyed interacting with students, using group collaboration to accomplish assignments, and appreciating the moment students demonstrated insight and knowledge. Faculty members perceived creativity as something *new and beneficial to society*; they felt there was or should be a strong relationship between creativity and engineering. Most of them believed that they, as faculty members, were creative and that their students were creative in different ways. Their major concerns about directly integrating creativity into their teaching included that the integration might be time-consuming, that the evaluation would be complex, and that they lacked the knowledge, facilities, resources, and soft skills necessary to perform the integration. Implications of these findings are discussed.

Keywords: creativity; engineering education; teaching philosophies; creativity incorporation