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Section I
Special Issue
Good Practices for Emergency Situations and Remote Regions – Part 1

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The COVID-19 pandemic forced many Colleges and Universities across the globe to deliver education online. This online switch was abrupt and challenging for both students and instructors. Here we summarize the challenges faced in the United States at the University of Illinois at Chicago (UIC) College of Engineering during online teaching in Spring 2020 as a result of the COVID-19 pandemic and provide recommendations for the online delivery of classes. To understand the challenges faced, surveys were administered to UIC engineering students (N = 580) and instructors (N = 93). Two student focus groups were also convened (N = 56, N = 40). After the shift to online education, UIC students wanted to be on campus but not if that posed a risk to their or their family's health. Students also perceived lower quality of education after the shift. UIC College of Engineering instructors felt mostly prepared to transition online but were concerned about student learning assessment methods. Most instructors felt their classes went well and, if their classes were online in Fall 2020, planned to teach them with at least some amount of asynchronous delivery. Whenever possible, we recommend a blended approach to online teaching, offering the flexibility of asynchronous content with the engagement of a synchronous class. Other specific recommendations for lab classes, fostering a sense of student community, and student learning assessment are provided to address concerns and challenges as indicated by those surveyed. Given the unknown future epidemiological changes and willingness or the ability of students and instructors to return to campus, it is prudent to prepare for online learning in a COVID-19 world. We provide definitions, examples, considerations, and suggestions to assist in the online delivery of classes to guide and assist in this preparation.

Keywords: COVID-19; engineering education; online learning; teaching tips; blended learning

The spread and threat of COVID-19 has brought the world under standstill. Educational institutions are not exempt. The pandemic has forced the universities to transform from traditional teaching-learning methods to web-based digital teaching-learning methods. Claims are being made that future teaching would be fully online rather than traditional or in-class mode. There are many challenges in implementation of online classes and at the same time there are possibilities to enhance the knowledge and resources required to build the global online education network. This paper reviews the challenges and possibilities in teaching and learning online, various technological tools and their outcome practiced by the academicians to conduct the lectures and assessment activities. A special attention has been paid to the impact COVID-19 on mental health and anxiety among the staff and student community.

Keywords: COVID-19; Online education; Ethics and Effectiveness; Student-centric approach; Technology enhanced learning

The COVID-19 lockdown since March 2020 necessitates higher education institutions to deliver education online. Although education institutions in high and higher middle-income countries could relatively easily transition face to face education to online delivery, most higher education institutions in low-income and lower middle-income countries were unable to do it. World-wide, more than half of the world's 1.5 billion students is out of online education activities especially in developing and emerging nations. Hence, the primary objective is to examine the difficulties and challenges experienced by some of those countries in their higher education institutions' transition to online education. The study focuses on internet infrastructure, accessibility, affordability, digital learning management system, academics and students' perspectives and digital knowledge gap related to online education. The study finds that poor or no internet infrastructures/connections, streaming devices, learning management system, inexperience in online education, and socio-economic conditions are the main impedances for slow or no transition to online education in most emerging and developing countries. Some action plans (recommendations) to overcome these challenges are also compiled.

Keywords: Online education; Learning Management System; Internet; emerging/developing countries; eLearning

Several studies have been able to explore students' reactions to how the COVID-19 pandemic has affected learning processes. However, most of that research is specific to medical education and, while there exist some contributions in the context of engineering education, student-centered studies seem to be very limited. This study examined the perception of being forced to move to online learning in a population of electronic engineering students attending the Electronic Circuits I (EC-1) course offered by Universidad Santiago de Cali, a private university in Colombia. Data was collected through a 6-item survey comprised of questions to be responded to on a 6-point Likert-type scale and a written essay. Most of the respondents provided positive feedback on the guidelines and preparation provided by the instructor for the transition to online learning. However, some students perceive that online learning is not sufficient to bridge the gap between theory and practice. Moreover, Internet service access and an adequate learning environment at home are essential for effective online learning. Based on the experience lived during the transition, some recommendations are also provided.

Keywords: Engineering education; COVID-19; e-learning, students' viewpoint; electronic circuit courses

Quality technical education on healthcare technologies is still inaccessible to young adults in low-resource settings due to high costs, low-tech environments, and gaps in learning materials. The online and open-source collaborative Project-Based Learning (PBL) methodology intends to introduce early-career engineers into the development of healthcare technologies by allowing students from all around the world, regardless of background or place of origin, to engage in collaborative design methods, the use of open-source resources and learning experiences from experts in the field. This paper discusses a case study in which the aforementioned methodology was implemented, the "COVID-19 Innovation Competition and Design Bootcamp 2020", which brought together 105 participants from 22 countries, mostly in Africa, to conceptualize the design of 10 medical devices in two weeks for an integral management of the COVID-19 pandemic that is applicable to other infectious disease outbreaks. The presented experience demonstrates that highly formative virtual PBL experiences can be carried out, in a cost-effective way and in connection with real societal needs, for which remarkable solutions can be found, by virtue of multidisciplinary and international cooperation. Our findings demonstrate that even if it is difficult to reach the degree of project completion achievable with longer-term and on-site design-build experiences, on-line PBL has been shown to promote students' professional skills in an effective way.

Keywords: Project-based learning; collaborative design; COVID-19; CDIO; medical device

This contribution is about the time and didactic efficiency of electronic education in training of future specialists in the field of applied informatics. We created two groups of students within our research: experimental and control group. Both groups had to create a mutual goal during the educational process (1 semester) – to design and program a robotic arm controlled by Arduino. The experimental group worked in the TinkerCad environment which is an online simulation playground aimed directly for designing and programming projects based on the Arduino platform. The control group did the experiment the conservative way: the education process was done by giving the students physical equipment with the necessary electronic components. The results of this experiment show us the time efficiency in the favor of online education, while the didactic efficiency reached the same level in both groups.

Keywords: time efficiency; online education; robotics arm

Most programming courses teach students how to write programs that produce the correct output without focusing on code quality. Although teaching about code quality is important, more emphasis is placed on code correctness. The reason is not its conceptual complexity but a lack of efficient methods for teaching good programming practices. This paper presents a code quality inspector named CQpy as a subsystem of an online judge for assessing both the correctness and the quality of programs submitted by students. Once the submitted code is judged to be correct, a student can further inspect code quality issues (CQIs) using CQpy. The timely feedback and automatic suggestions provided by CQpy help students improve their code quality through self-study. A controlled experiment revealed that there were thousands of unsolved CQIs in the programs submitted in a Python course in 2019 without CQpy. However, when CQpy was used, 91% of the detected CQIs were addressed by students who took the same Python course online during the COVID-19 pandemic in 2020. According to a student survey conducted at the end of the course, 90.12% of the students were satisfied with using CQpy in the online course, and 81.7% affirmed that they had improved their skills related to code quality after taking the course. Based on the experimental results, we identified a set of common CQIs representing the most frequent mistakes made by programming students. The results of this study could enhance the code quality education in future online Python programming courses.

Keywords: code quality inspection; automatic programming assignment evaluation; online course

The rapid spread of COVID-19 across many parts of the United States (U.S.) in the early spring of 2020 required universities across the country to make dramatic changes, the most visible of which was closing their campuses to faculty and students and moving instruction online. Information about how universities, engineering programs, and engineering faculty in the U.S. responded to the changes remains limited. The purpose of this exploratory study was to identify the changes engineering faculty made to policies, practices, and courses and to begin to understand how the changes affected undergraduate engineering students. We utilized a cross-section research design in which we collected data from over 200 engineering faculty via an online survey. We analyzed the data descriptively and using basic inferential statistics. We found that all universities moved instruction online and most closed campuses. Multiple offered additional financial aid to students. Few engineering units took steps beyond what university leaders already had. Engineering faculty implemented a range of changes to their courses, including the elimination of assignments. We observed that most changes made assignments less collaborative and interactive. Finally, faculty reported hearing about students' multiple concerns, ranging from academic and technical challenges to challenges at home. We encourage universities to offer more support to faculty and students as online learning continues across the U.S. In particular, we recommend more outreach to students to build and maintain strong ties to the university and engineering units.

Keywords: undergraduate engineering education; COVID-19; student experience; instructional change

The global pandemic situation posed the challenge of modifying teaching at all educational levels. Higher education also had to transform its face-to-face learning, to distance teaching. This paper focuses on the faculty members' perception about the sudden change that they had to make to maintain a high-quality teaching in the context of a Spanish technical university. An ad-hoc survey was responded by 577 faculty members. It analyzed the effort and time spent compared to their previous teaching, the use of different ICTs, the difficulties perceived and their preferences of future teaching and training modalities. The faculty show that it has been much costlier than usual, regardless of their age or seniority. There has been progress in ICT knowledge and use, especially for faculty members who have not received prior training, and 57% of faculty members intend to incorporate modifications in their future teaching, such as new resources and materials, after-class questionnaires and distance mentoring. In any case, the older and with higher category faculty are inclined towards the face-to-face format for future teaching, while the younger ones and from initial professional categories bet on digitization to some extent. The online assessment stands out as a great difficulty. Also, the students' low participation, the greater workload and time spent and the inability to receive feedback from students due to lack of eye or personal contact have been pointed out as the difficulties to carry out adequate monitoring. In short, the digital divide in university teaching has found in the emergency remote teaching an opportunity to promote the improvement of learning, facilitating the revision of pedagogical approaches, updating methodologies and evaluation strategies that will promote the digital transformation of university education.

Keywords: ICT skills; engineer education; faculty training

Present study aims to investigate the implications of COVID-19 on the learning satisfaction of engineering students. In this regard, data were collected from 623 students living in the urban/rural areas and studying in the public/private universities of a developing country. Authenticity of the data was checked with the help of KMO (Kaiser–Meyer–Olkin) and Bartlett tests, while descriptive statistics, ANOVA, and multiple regression were used for data analysis. The results indicated an asymmetrical pattern, as the students living in urban areas and studying in private universities expressed the highest level of satisfaction (84.6%), while the students living in rural areas and studying in public sector universities expressed the lowest satisfaction scores (54.1%). It was observed that home learning conditions, availability of suitable computing devices, quality of internet services, and instructional methodology had the greatest impact on student learning satisfaction. Afterwards, structured interviews were conducted with the concerned stakeholders to develop a remedial framework for the guidance of universities. Although, the focus of the study was engineering students, yet the insights of the paper are quite generic and can be applied to other educational fields as well.

Keywords: COVID-19; student satisfaction; online learning; developing countries; urban students; rural students; engineering institutions

COVID-19 has caused and continues to cause many changes in the way people around the world live. This study analyzes how COVID-19 and the adopted emergency remote teaching (ERT) methods have influenced university education, focusing on their impacts on project-based learning (PBL) methods. For this purpose, a comparative study is made between students' stress and satisfaction levels in a PBL course, before and during the COVID-19 pandemic. The results reveal that the emergency remote teaching methods do not necessarily affect the levels of stress and satisfaction of students, as compared to the usual face-to-face teaching, if adequate measures and monitoring are undertaken. Our results also show that, in face-to-face teaching, professors have a leading role for balancing the stress and satisfaction variables. However, in emergency remote teaching, students themselves assume a higher degree of responsibility for balancing such variables, which can constitute an interesting complement to other strategies for the promotion of soft skills.

Keywords: COVID-19; higher education; Project-Based Learning; workload stress; students' satisfaction

Section II
Contributions in: Learner-Centered Education, Academia and Industry, Project-Based Learning, First Year Engineering, Design Process, Spatial Ability, Online Learning, Storytelling, Active Learning, Service Learning, Blended Learning, Work-Integrated Learning, Chemical & Petroleum Engineering, Electrical Engineering

Educational institutions aim for preparing students for their future lives. Yet, most schools focus on teaching static knowledge rather than fostering social and personal competences required in the 21st century. This paper proposes a self-driven, learner-centered approach to education named "learning office". Existing literature is reviewed and a questionnaire estimating selected 21st century skills is developed. A survey employing the questionnaire was conducted with 12 cohorts of the grades 9–11 of an Austrian higher technical secondary vocational school. Six cohorts were taught in the new approach. The analysis of the 312 responses showed that learning office students reported significantly higher overall scores in critical thinking, self-efficacy, personal responsibility, and openness at grade 10. Learning office students were also significantly more likely to provide a meaningful written reflection. We conclude that the learning office approach indeed fosters 21st century skills.

Keywords: 21st century skills; learner-centered education; learning office; student-centered learning; upper secondary school level

This paper presents a case study of a mutually beneficial, 18-month long industry and academia partnership engagement process to assist others in establishing similar relationships. The partnership highlighted began with a single, unfunded graduate class project

for a team of six students. Within 18-months, the partnership grew to 45 classroom projects, senior project designs (including capstone projects), graduate theses and dissertations, collaborative vendor/student research, and student competitions. During the three years following the 18-month case study, the industry-academia partnership continued to grow and resulted in multiple industry-funded research projects led by university faculty. Lessons learned from the partnership include 10 research-based collaboration strategies ranging from short term, low cast classroom projects to high cost, long term funded programs as well as nine industry brand awareness strategies for recruiting via future employee pipelines within the university. These lessons also include 11 project engagement steps that faculty can use to grow future funding opportunities. These engagement steps range from focusing on recruiting the right contact and champion, understanding the sense of urgency in project execution, to sustaining long partnered collaborations. Furthermore, the case-study established the need for a "bilingual" contact to support the communication between industry and academia partners.

Keywords: industry engagement; partnerships; classroom projects; student pipeline; industry funding; classroom involvement strategies

The modern engineering profession is dynamic, filled with uncertainty and requires a technical background as well as interpersonal skills. The demands placed on modern engineers are to navigate competing priorities set by clients, regulating bodies, environmental groups, and the public at large to take decisive action to solve the problems faced by industry. For engineering students to be prepared for the challenges they will face in their careers, they need to gain experience working in a dynamic environment to solve projects and problems that diverge from the theoretical realm and enter a practical landscape similar to what they will encounter in industry. One way is through engaging with an on-campus project-based learning (PBL) center as a student intern. A PBL Center relies upon a pedagogical strategy where student learning centers around projects under the guidance of faculty mentors. The PBL Center also functions to allow industry and community partners to engage with faculty and student interns. The Concept Center at Weber State University is modeled after PBL pedagogy and functions to connect student interns employed at the center with sponsored projects. This paper discusses the application of PBL in the Concept Center to achieve a double mission of being an active community member by connecting academia with industry and community members and providing opportunities for students to gain needed skills in problem solving and project engineering. A summary of intrinsic benefits is presented in this paper with examples of past projects completed at the Concept Center by student interns. Additionally, key lessons learned from the operation and management of the Concept Center are provided.

Keywords: Project-based learning; student intern; Concept Center; lifelong learning; cross-functional teams

This study sought to examine the possible differences and changes in constructs within motivation for first-year students during the revision of a first-year curriculum. Data were collected quantitatively through a pre-and-post survey with 1,037 (pre) and 1,056 (post) first-year engineering students at a research-intensive technical university. The work was framed by the Expectancy-Value Theory of Motivation. Results suggest that students' motivation decreases significantly over the first year in an engineering program, this aligns with the literature on engineering-related motivational beliefs. Similarly, our findings suggest that in the revised version of the course, the motivational constructs did not change which can be interpreted as an indicator that the new version of the course had a positive impact in mitigating drops in students' motivational beliefs. Additionally, results show that the "Motivational Beliefs" survey provides a useful tool that can be applied in foundational courses to reveal critical information about students' motivation, attitudes, and beliefs about engineering and their intention to completing an engineering degree. We provide implications for research and practice.

Keywords: motivation; first-year engineering; expectancy-value; motivational beliefs

The robotics based Elementary Engineering Curriculum – used by students in this study – and other similar projects have the potential to increase the STEM pipeline but elementary engineering is not well-understood. Research is needed to understand how to teach engineering to students as their cognitive, motor, and social skills rapidly develop in elementary school. The authors conducted a cross-sectional case study of six grade 2 and six grade 6 elementary robotics students in the context of established K-6 elementary robotics curriculum. Students were videotaped doing an open-ended engineering task based on LEGO robotics using talk-aloud and clinical interview techniques. The engineering design processes were analyzed and compared. Significant differences were found in final projects and engineering design process related to the complexity of the ride they tried to build and the key skills and structural knowledge they brought to the task. Seven key factors identified consisted of three cognitive skills of cognitive flexibility, causal reasoning, and planning ability, three domain specific process skills of application of mathematics and science, engineering design process skills, and design principles of stability, scale, and the structural knowledge they had of LEGO robotics, most pointedly, LEGO connection knowledge. Implications of these findings for teachers are given.

Keywords: P12 engineering education; engineering design process; LEGO robotics; complexity; structural knowledge; design principles

The preponderance of growth mindset intervention studies focus on elevating a growth mindset by teaching students that the mind is like a muscle and that it grows stronger through rigorous mental exercise. But, there is also the potential to elevate a growth mindset via strengthening intelligence. Spatial visualization promotes successful engineering performance and many college students would benefit from improved visual-spatial ability. The primary objective of this study was to examine whether a brief online workshop that teaches visual-spatial skills (e.g., mental rotation) would increase both visual-spatial ability and a growth mindset for spatial intelligence. This study included 296 undergraduate mechanical, systems, industrial, and aerospace engineering students that participated in a total of 3.5 hours of a workshop that trained students in visual-spatial thinking over the course of 7 weeks. Outcome measures included pre/post Purdue Spatial Visualization Test-Visualization of Rotations (PSVT:R) and pre/post growth mindset for spatial intelligence. Paired sample t-tests indicated that students improved significantly from pre to post-workshop on both mental rotations (Cohen's $d = 0.38$) and growth mindset ($d = 0.33$). Women improved as much as men on both measures. This study suggests that an online visual-spatial intervention can efficiently promote stronger visual-spatial ability and a growth mindset.

Keywords: growth mindset; visual-spatial ability; STEM; college students; intervention

In 1993, a Southwestern public university in the United States was a founding member of the Foundation Coalition (FC), a 10-year multi-university NSF initiative to improve first- and second-year engineering education. In 1998, the FC curriculum was employed universally; however, in 2003, the engineering college fragmented the first-year curriculum: Track A (project-based learning), Track B (computer and electrical engineering), and Track C (FC concepts in chemical and petroleum engineering). Using the logic model for the Theory of Change, this study explored the longitudinal effects of the Tracks A and C on chemical and petroleum engineering student graduation outcomes: graduation in engineering, time-to-graduation, and cumulative GPA. Participants were

1,022 students who started in chemical or petroleum engineering and enrolled in Tracks A or C from 2003–2007. The graduation outcomes of these students were completed by fall 2016 and were compared using descriptive and inferential statistics. Within a major, tracks had no significant effect on time-to-graduation. However, Track A petroleum engineering students showed improved graduation rates in engineering and Track C chemical engineering students had significantly higher cumulative GPAs. When particular student backgrounds and their first-semester course grade were controlled, Track C students showed significantly reduced time-to-graduation and increased cumulative GPA. This study shows that a first-year engineering curriculum can dramatically impact student outcomes upon graduation.

Keywords: first-year engineering; chemical engineering; petroleum engineering; graduation outcomes; Theory of Change

Storytelling can be an effective pedagogical tool to transmit technical information and increase engagement. Storybooks are a visual medium where the technical content can be explored through narrative and imagery. A storybook was written and illustrated to translate the functionality of a breadboard and the process of making a circuit into a fictional narrative. Through observation and a quantitative assessment, this study explores the question: is a storybook as effective as a traditional lecture to transmit technical content? One section of a first-year engineering design course ($n = 29$) had a traditional lecture to learn about breadboards, and the other section ($n = 43$) used the storybook. Participants in both sections were timed to see how long it took to replicate two circuits. They completed a short assessment to measure their understanding of the functionality of breadboards. Participants who used the storybook completed the activities significantly faster ($p < 0.001$) and demonstrated a better understanding of the material (non-significant) than participants who received a lecture. Though the storybook was developed for audiences of all ages, findings of this study are limited to undergraduate engineering students.

Keywords: engagement; instructional methods; electrical engineering; active learning; storytelling

Teaching and research are two basic functions of a University, and both have to be integrated into students' learning as well as in their initiation into the scientific research. Geomatics Engineering has evolved in recent years, supported by continuous technological and methodological development and the students need updated learning approaches. This paper describes an innovative experience carried out at the University of Jaén (Spain) to promote the initiation in scientific research within the framework of a research group of Applied Geodesy and shows how active learning environments may be designed with all their components acting congruently to support deep approaches to learning. Three case studies located at different academic levels and with six participating students are presented. These show how the geodetic infrastructure is a valuable tool for introducing students to applied scientific research. This approach provides research opportunities to undergraduate and graduate students, it is sustainable in collaboration with a consolidated research group, and it promotes the dissemination of research results by peer-reviewed papers and scientific publications with students as co-authors.

Keywords: active learning; engineering education; geomatics engineering; scientific research; case-studies

Blended learning which is an advanced teaching strategy integrating techniques used in Small Private Online Courses (SPOCs) and those in traditional classrooms is increasingly adopted in many courses. The aim of this study is to evaluate whether blended learning in a Practical Introductory Engineering Course can improve students' performance, classification and satisfaction. To do so, a blended learning mode was designed and the blended learning group (182 students) of the academic year 2019–2020 was compared with the traditional learning group (226 students) of the academic year 2018–2019 in terms of the students' performance and classification. Besides, we evaluated the students' satisfaction in blended learning using designed questionnaires. The results show that students in the blended learning group have better performance than those in the traditional group. Regardless of the practical operation scores or the final grades, the interval distribution of scores in blended learning group was about 5 points higher than that of the traditional learning group. We also utilized a classifier based on our proposed deep learning model and verified through a comparative study that the classifier has the best performance among several existing models. The results also reveal that comparing with traditional learning, the accuracy of using the proposed model to classify students in blended learning was improved by 16.45%. As far as the questionnaire survey is concerned, most students had a positive view of employing the blended learning in the course. Overall, these results can serve as reference and guidance for future engineering practice courses.

Keywords: blended learning; students' performance; classification; the deep learning model; satisfaction

Work integrated learning (WIL) has increasingly been becoming an important part of engineering higher education. This paper analyses the major research that has occurred primarily in the last decade in the area of engineering WIL. Research studies have identified industry and community needs and revealed the shortage of skilled graduate engineers in the Australian industry owing to the scarcity of industry-ready graduate engineers. This situation has resulted from a mismatch between the requirements and the number of skilled engineering graduates from Australian universities. The authors identify that the duration of WIL available for Bachelor of Engineering programs is very short. Thus, engineering students are not receiving adequate workplace learning opportunities to develop industry-readiness. Current WIL for engineering students is not effectively coordinated due to the absence of an effective framework. Students often need to organise their placements because many universities provide minimal support to individual students. The authors explore the research on WIL and its impact on engineering education quality, industrial productivity and graduate employability. There is a substantial need to increase the weightage of WIL and improve the outcomes of engineering education via a more effective work integrated approach. This paper emphasises the necessity of appropriately structuring WIL in empirical learning practice and propose an enhanced WIL (EWIL) framework to address the gaps in the effectiveness and quality outcomes of engineering education.

Keywords: engineering education; bachelor of engineering; work integrated learning; WIL; workplace learning; industry engagement