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Section I

Special Issue

Case-Based Learning in Engineering and Applied Science Education

Guest Editors

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Artificial intelligence is becoming more and more popular, people applied AI in speech translation, object detection, and prediction in AI and machine learning algorithms. Teaching AI is the trend in the university. There are many AI algorithms, but students are not familiar with how to select analysis algorithms to solve the real case. AI cases are crossing fields and industries. In this study, case-based learning is applied in AI university courses with Microsoft Azure studio. Case-based learning not only makes better learning performance, but also promotes significance in "systematic analysis", and "thinking out of the box".

Keywords: teaching AI; case-based learning; machine learning; Microsoft Azure

This research investigates globally dispersed innovation teams involved in explorative projects within an engineering graduate course employing problem-based learning. Utilizing insights from a longitudinal study, the objective is to identify how to enhance both individual learning and team performance, thereby increasing the likelihood of a successful outcome. Initial observations revealed common patterns in learning experiences among the top-performing teams, prompting further investigation into how supporting cohorts might positively influence both team performance and students' learning experiences throughout the course. In addition to advancing comprehension of innovation team performance, the study introduces two lightweight tools designed as shared visual representations of the team's exploration journey. These tools can assist supporting cohorts in guiding teams effectively. This research augments the existing body of knowledge surrounding the achievement of breakthrough innovations. It provides understanding about how to facilitate team performance and individual learning within globally dispersed innovation teams undertaking explorative projects. The proposed lightweight tools offer practical solutions to enhance the supporting cohort's ability to guide and impact team performance and individual learning experiences. This study holds implications for academia and industry, particularly organizations reliant on radical innovation for competitiveness and future-proving. Lastly, the study's findings could inform the design and delivery of future problem-oriented, project-organized learning-based courses in engineering education.

Keywords: project based learning; case based learning; engineering design

To create effective learning environments for students, it is important to continually evolve curriculum and teaching strategies. This may involve an open pedagogy that encourages research within the classroom, promotes real-world problem-solving, and incorporates case studies, projects, and videos to enhance personalized and collaborative learning. These strategies can be implemented in both in-person, blended, and online learning settings to ensure that students receive a well-rounded education. This study delves into the practice of open pedagogy through the principle of Two-Eyed Seeing, which helps to integrate the powers of Indigenous ways of knowing with one eye, and Western ways of knowing with the other eye, for the benefit of teaching ethical professional practice in undergraduate engineering and computing programs. The students' self-assessments and feedback revealed noticeable improvements in their skills and competencies. This integrated approach to curriculum and pedagogy fosters critical and creative thinking in learners and cultivates a growth mindset that empowers them to take charge of their learning.

Keywords: open pedagogy; two-eyed seeing; ethical space; research-based learning; case-based learning; project-based learning; video-based learning

Case-based learning (CBL) is an established learning approach adopted by various disciplines which challenges students to solve real world problems, resulting in achieving higher levels of cognition. This active-learning pedagogical method has been continually practiced in several courses taken by students in the undergraduate engineering technology program, Biotechnology at McMaster University. The intent of this study is to compare the perspectives of students on the effectiveness of virtual CBL versus in-person CBL, directed pre- and post-pandemic respectively in the upper year course of the program, Industrial Biotechnology completed in Fall 2021 (conducted virtually) and Fall 2022 (conducted in-person). The resultant findings indicate that CBL proved to be a superior learning tool for an in-person delivery platform, opposed to a virtual platform. Although students in a virtual learning environment stated that CBL did not have a major effect on their communication and teamwork skills, majority of them agreed that CBL enhanced their critical thinking skills, problem-solving skills, course performance, self-confidence, and exhibited a deeper conceptual understanding. Acclimatized with the virtual learning environment, students also found it challenging to reform back to an in-person learning environment.

Keywords: CBL; virtual learning; in-person learning; engineering technology; biotechnology; education

A Work-based Project Practice Motivated by Problem-Solving in Software Engineering
Ga Xiang, Lei Wang, Xuan Sun and Weiran Tang

Work-based project practice was introduced to decrease the gap between academics and industry for software engineering education. For work-based project practice, the methods of inspiring students' learning motivation need to be studied more. In this paper, to inspire students' motivation better, at first, a work-based project practice framework with problem-solving is proposed; secondly, a role-driven cooperation mechanism is constructed which simulates the real development team's working mechanism; finally, a project tracking method is defined which can motivate students and evaluate the practice. In the past 3 years, the proposed framework, mechanism, and method have been applied in our research. It shows students' motivations are improved by facing engineering problems, taking specific roles, and tracking project status weekly, and the students are inspired better to apply software engineering knowledge to solve complex engineering problems.

Keywords: problem-solving; work-based project practice; software engineering education; cooperation mechanism; regular project tracking; motivation

The Effects of Online Project-based Learning with Real Enterprise Data in Two Interdisciplinary Courses
Kim Moon-Soo

This study is to analyze the results of applying the online project-based learning model with various enterprise data to two interdisciplinary curricula, engineering economics and engineering accounting, targeting engineering students in the corona pandemic times from 2020 to 2022. In particular, by comparing 2020, when simple online lectures were not applied with PBL, and 2021 and 2022, when online PBL was applied based on enterprise data, the effects are compared and analyzed, and educational implications are identified through a comparison by course. As a result of comparative analysis of students' lecture evaluation, the interdisciplinary courses applied with online PBL based on enterprise data were mostly effective in terms of inducing student-centered learning, online PBL adequacy for learning, and learning effect and satisfaction. Also, from the student survey, it was found that students expect that the possibility of using it in future companies will be high. In addition, the results of this study were able to identify educational implications for the application of company case-oriented PBL to various curriculums in the future.

Keywords: online project-based learning (PBL); enterprise data; engineering economics; engineering accounting; interdisciplinary courses; corona pandemic

Section II

Contributions in: Entrepreneurship, Assessment, Team-Based Learning, STEM, Graphics Interpretations, Student Engagement, Student Outcomes, Modeling, Visual Patterns, Eye-Tracking, Industry 4.0, Self-Efficacy, Competence Development, Career Path, Life-Satisfaction, Race & Gender, Choice of Major

Assessment of Student's Entrepreneurial Self-Efficacy in Entrepreneurship Courses: A Latent Mean Analysis
Heydi Dominguez and Prateek Shekhar

In the 21st century, preparing successful engineering graduates entails establishing a solid foundation in engineering disciplines and supplementing it with interdisciplinary expertise, particularly from non- engineering fields. An illustrative example of this approach involves the integration of entrepreneurship education programs (EEPs) into undergraduate engineering curricula, exposing students to entrepreneurial practices like creating business models and engaging in pitch competitions. To maximize the impact of EEPs, further research is essential to comprehend their nuances, especially regarding assessment of student outcomes with focus on students' demographic backgrounds. In this quantitative study, we contribute to the growing engineering entrepreneurship research literature by examining changes in students' entrepreneurial self-efficacy (ESE) before and after taking an entrepreneurship course within the College of Engineering, with a particular focus on gender differences. Following Bandura's self-efficacy theory, we conceptualize ESE as a multi-faceted construct comprising five sub-constructs: searching, planning, marshaling, implementing people, and implementing finance. Through a comprehensive analysis of 255 pre-course and 228 post-course responses from students, our latent mean analysis reveals significant positive changes in ESE across various sub-constructs, except for implementing people among female students. This highlights the need for further research to address pedagogical aspects of EEPs in engineering fields and promote inclusivity for historically marginalized student groups, ultimately extending the benefits of EEPs to a diverse student population.

Keywords: entrepreneurship education; gender; quantitative; self-efficacy

Evaluation of Bias in Peer Assessment in Higher Education
Jacklin H. Stonewall, Michael C. Dorneich and Jane Rongerude

Small group, active learning strategies have increased student achievement, attendance, engagement, and overall learning outcomes. Peer assessment is an important aspect of team pedagogy. It increases individual accountability, improves team functioning, and contributes to a sense of belonging among teammates. However, perceptions of unfairness undermine many positive outcomes of team learning and peer assessment. Students worry that their peers are not impartial raters; indeed, research has shown that they are not. However, a broad investigation of bias is needed. Specifically, there is little peer assessment data that cuts across classes, departments, and academic fields, as this information tends to be challenging to collect into a single dataset. This project aimed to explore bias in peer assessment from multiple perspectives through a literature review, surveys of students and instructors, and an analysis of peer assessment ratings given and received. The first study broadly asked instructors about the occurrence of bias in their classrooms and actions to mitigate it. The second study asked students about their peer assessment experiences and perceived biases. The third study analyzed over 20,000 peer assessment ratings to investigate bias. Both instructors and students detailed bias in their classrooms and with assessments. Evidence of bias was shown in the peer assessment scores, which student achievement cannot fully explain. The results demonstrated that the experiences of women and students of color in these classrooms differ from those of their peers regarding assessment. By understanding where and how bias occurs in peer assessment, training can be designed to target problem areas and improve the fairness of assessment directly. This could ensure that the positive outcomes associated with learning teams are shared among all students.

Keywords: team-based learning; student assessment; bias; active learning; teams

Perceptions of Engineering and Technology High School Teachers and Policymakers towards 21st Century Skills 557–571

Amona Abu-Younis Ali, Shahaf Rocker Yoel and Yehudit Judy Dori

Engineering professions demand that students possess 21st century skills, including interpersonal skills. This, in turn, requires high school teachers to master these skills while teaching engineering and technology (E&T) subjects. Active learning methods provide opportunities to develop these skills among students. This research aims at investigating E&T teachers' and policymakers' perceptions regarding 21st century skills. Participants included 96 high school E&T teachers and 15 policymakers. The research applied a convergent parallel mixed methods approach, with data collected from a perception questionnaire and interviews. Based on the participants' perceptions, the three most prevalent 21st century skills were collaboration, digital and information literacy, and self-regulated learning (SRL). Positive correlations between these skills were exhibited, indicating that they reinforce each other. Two factors – SRL - Time Planning & Management and Problem Solving & Ideas – were found to be significantly higher for teachers over 40 years old than for teachers who were 40 years or younger. New categories have emerged from the qualitative analysis in the context of E&T education in high school. The questionnaire developed can serve as a reliable and valid tool for examining teachers' and policymakers' perceptions about 21st century skills E&T education. Policymakers aiming to enhance E&T education at the high school level can benefit from the research findings.

Keywords: 21st century skills; engineering education; technology education; engineering and technology (E&T) education; engineering and technology (E&T) teacher; policymaker; high school; STEM; interpersonal skills; active learning

How Engineering Students Understand and Interpret Graphics Using Spreadsheets an Empirical Study in Physics Courses 572–582

Daniel Sánchez Guzmán and Erika Cervantes Juárez

The process of learning graphics is fundamental to students' instruction; it is applied to interpreting data, understanding information, and making decisions based on graphical representations. This instruction began in the early years and continued through post-graduate instruction. The use of graphics as a process of communication between people is crucial for aiding the decision-making process in various phenomena. Much research has been conducted to analyze the challenges of learning graphic interpretation and understanding, exploring the types of graphics, variable behavior, and students' misconceptions. The learning science and engineering using the electronic spreadsheet cycle (LSEESC) methodology has demonstrated a positive impact on students' learning and skill development. This impact includes numerical manipulation, understanding mathematical models, and the process of generating and interpreting graphics correctly. Present research is an empirical examination of implementing the LSEESC methodology in three different learning scenarios (virtual, hybrid, and face-to-face). Preliminary results demonstrate a positive learning process in graphics generation, understanding, and interpretation among first-year engineering students taking physics courses. To analyze this impact, quantitative methods such as Normalized Conceptual Gain (NCG), Concentration Factor (CF), and Rasch's index were applied, all results present positive values for all the statistical analyses. We concluded that the effectiveness of the LSEESC methodology is independent of the learning scenario, demonstrating its applicability to the learning process of graphics generation, understanding, and interpretation for engineering students. Additionally, the methodology complements the development of other skills such as numerical manipulation and the understanding of mathematical models.

Keywords: graphics interpretation and understanding; engineering students; LSEESC methodology; physics courses; virtual; hybrid; classroom learning scenarios

Analysis of First-Generation Engineering Students Engagement and its Relation to their Academic Performance 583–590

Abigail Lehto and Ning Fang

First-generation college (FGC) students differ from their continuing-generation counterparts in many aspects, such as having a lower grade point average (GPA), a higher likeliness to switch majors out of science, technology, engineering, and mathematics (STEM), a lower level of engagement in and a lower likeliness to graduate in STEM majors. Looking to take steps to aid FGC engineering students with their current struggles, the present study aimed to investigate the educational activities they were engaging in, and how these activities relate to their GPA, an overall measurement of students' academic performance. A total of 28 FGC engineering students at the authors' institution took the National Survey of Student Engagement (NSSE). Student responses were related to 4 themes and 10 engagement indicators (EIs) of the NSSE and were related to student GPA as well. It was found that FGC engineering students had high levels of engagement in educational activities related to two themes (learning with peers and academic challenge) and two EIs (learning strategies and discussions with diverse others). Example learning strategies that students use include pre-reading the course material prior to a class and summarizing after class what they have learned in a class period. On the other hand, from the present study it was also found that FGC engineering students had a low level of engagement in the experiences with the faculty theme and the student-faculty interaction ET (i.e., student interaction with faculty). Student GPA was statistically significantly correlated with the supportive environment EI with a moderate Spearman correlation coefficient of 0.414 and p-value < 0.05.

Keywords: student engagement; first-generation college (FGC) students; engineering; descriptive and correlational analysis

Design and Implementation of a Comprehensive Platform to Assess Students' Outcomes 591–605

E. M. Shaban, Abdullateef H Bashiri, Waleed Zakri, Anil Kumar Deepati and Farooque Ahmad

Direct assessment of Learning Outcomes (LOs) is a crucial issue in higher education, but it is a tedious process and consumes time to implement. This is because the assessment process should define various artefacts such as Performance Indicators (PIs) and Level of Learning (LoL) for each LO, as well as the design and merging of all assessment tools. Moreover, the assessment process should be fair and unbiased to provide accurate assessment for decision making. In some practices, instructors may rely on only one comprehensive assessment tool to evaluate the LOs which drastically affects the accuracy of the assessment process. In this paper a systematic approach is implemented through a platform for which all aspects necessary to assess the LOs are defined in a convenient and organized way. The proposed platform automates the process of the formative assessment of the targeted LOs for every assessment tool, in a course, and subsequently acquire the summative assessment of the LOs together with their impact on the Students Outcomes (SOs) of the academic program through the predefined PIs. Moreover, the feasibility of the assessment tools (reliability and validity) is introduced to ensure realistic LOs assessment. The platform was examined on different academic programs, but the focus was on the Mechanical Maintenance Engineering Technology (MMET) Program at the College of Applied Industrial Technology (CAIT) at Jazan University in KSA. The acquired results showed easiness of use of the platform and time saving of the faculty members. Moreover, it provides immediate feedback for any in-semester exam to explore strengths/weaknesses and to address the shortcomings ahead of the end of the semester.

Keywords: learning outcomes (LOs); direct assessment; feasible assessment

A Perspective on Micro-Courses and Building Information Modeling for Enhanced Teaching and Learning 606–613

Liting Bai and Qi Chai

The Application of Digital Technology in Architectural Construction Education from the Perspective of Cognitive Theory: Emphasizing the Practical Value of Constructivism and Connectivism in Cognitive Theory, and Deepening its Role in Advancing Education. This study aims to investigate the impact of micro-course platforms and BIM technology on student learning through a survey of architecture students in control and experimental groups (N = 100). The results indicate that students taught with micro-courses and BIM technology exhibit higher levels of engagement, understanding, mastery, and application of digital technology compared to traditional teaching methods. This contributes to the validation of the usefulness of combining micro-courses and BIM technology in teaching construction concepts. Therefore, within the framework of cognitive theory, applying digital technology effectively improves the efficiency and quality of architectural construction education in terms of both theory and practice.

Keywords: cognitive theory; digital technology; construction education; teaching and learning; application research

Academic Performance and Visual Patterns in Reading Technical and Design Articles among Industrial Design Students 614–623
Yongchun Mao and Guolin Zhang

Articles that combine text and images are common learning materials in industrial design education, presenting with multimedia reading features. However, the visual patterns employed by industrial design students when reading technical and design articles, as well as the relationship between patterns and students' reading performance, remain unclear. This study utilized eye-tracking technology to investigate the attention distribution and fixation transition patterns among industrial design students when reading technical and design articles. The study also examined the correlations between eye-tracking metrics and reading performance. A total of 54 industrial design students (27 lower-grade and 27 upper-grade) read two types of articles (technical and design articles) and completed recall and inference tests. The findings revealed that in the technical article, participants exhibited increased attention to texts and followed a top-to-bottom reading order. In contrast, the design article received greater attention to images, and there was more interaction between text and images. Recall scores for the technical article positively correlated with reading time and fixation count on texts, while inference scores for the design article positively correlated with reading time and fixation count on images. Upper-grade students demonstrated greater focus on images and achieved higher inference scores in the design article compared to lower-grade students. These research findings contribute to enhancing the education of industrial design students. In industrial design education, emphasis should be placed on enhancing students' ability to process information from pictures and their ability to connect texts with pictures.

Keywords: multimedia reading; eye-tracking; design education; visual patterns; engineering students

Readiness to Teach Industry 4.0 among University Lecturers in Malaysian Urban Universities 624–638
Zariv Long-Kwan Chew, Ananda Kumar Palaniappan and Chooi-Seong Lai

The rising unemployment rates among fresh graduates have been attributed mainly to skill deficiency in the job market especially in this era of Industry 4.0. Thus, it is important to investigate the level of readiness of lecturers to teach Industry 4.0 technologies in the different types of universities and disciplines. Descriptive survey research was undertaken using 84 lecturers from private and public Malaysian urban universities. A questionnaire based on the 21 dimensions from the Ministry of International Trade and Industry (MITI) Malaysia (2018) Industry4WRD Readiness Criteria Model was constructed to measure lecturers' readiness to teach Industry 4.0. The validity and reliability of the questionnaire were high. Results revealed that the lecturers had low level of readiness to teach Industry 4.0 skills, there were no significant differences in readiness to teach Industry 4.0 between private and public university lecturers on all dimensions, and there were also no significant differences in readiness to teach Industry 4.0 between Engineering and Computer Science lecturers. Results from this study could be used to identify and rectify lecturers' lack of readiness to teach on specific Industry 4.0 dimensions. Future research should focus on replicating this study with a larger sample size and identify approaches to improve lecturers' readiness to teach Industry 4.0.

Keywords: Industry 4.0 education; education 4.0; readiness to teach; higher education; engineering education; educational psychology

Perceived Benefits of a STEM Intervention Program and Engineering Self-Efficacy: A Multi-Method Investigation 639–655
Selyna Pérez Beverly, Christina S. Morton and Lisa R. Lattuca

This study explored how students in an intervention program for underrepresented populations pursuing engineering in a U.S. university perceived the program's benefits and the relationships of those perceptions with participants' engineering self-efficacy in their first year of undergraduate study. Data came from a multi-method, longitudinal study of the U-ENGIN program situated in a highly selective research university in the U.S. Midwest. Participants included 147 U-ENGIN students and 78 College of Engineering comparison group members for a total sample size of 225 over a time period of four years. Results are reported for Students of Color, White students, and a comparison group of students that did not participate in the intervention program. In this study, Students of Color refers to African Americans, American Indians or Native Americans, Asian Americans or Pacific Islanders, Latinx, and any non-White race specified by the respondents. Findings indicate the program contributed to increased engineering self-efficacy for Students of Color, while support networks cultivated through the program and exposure to engineering prerequisites prepared them for their academic experience. The study provides insight into how elements of a STEM intervention program can contribute to the self-efficacy of underrepresented students and potentially impact student success.

Keywords: engineering self-efficacy; STEM Intervention Programs; Students of Color

Reconstruction of a Curriculum Framework in Vocational Colleges for Comprehensive Competence Development 656–668
Lizhi Tao, Prasert Ruannakarn, Hengliang Cheng, Fei luo, Xuyun Peng and Zhongbao Ma

To adapt to the demands of industry and facilitate the transformation of vocational colleges from mere skills training to comprehensive competence development, reconstructing the curriculum framework is imperative. This study focuses on the elevator engineering technology major in Chinese vocational colleges, utilizing Taylor's theory and grounded theory. Drawing on evidence from interviews and open questionnaires with industry experts, the research aims to elucidate the key elements and hierarchical structure of the curriculum framework in vocational colleges. By enriching the theory of curriculum framework construction, this research deepens our understanding of curriculum reconstruction. The study provides insights to help Chinese vocational colleges overcome challenges in curriculum reconstruction. The proposed curriculum framework emphasizes interdisciplinary education, professional practice, teamwork, and other aspects, ultimately aiming to enhance students' comprehensive competence.

Keywords: vocational colleges; curriculum framework reconstruction; grounded theory; comprehensive competence

Beyond the GPA: Factors Influencing Life Satisfaction of Engineering Undergraduates 669–677
Dragan Lj. Bjelica, Dejana Pavlović and Luka Petrović

This study investigates what factors determine general life satisfaction among engineering students in Serbia. A total of 405 students from engineering faculties have participated in the study. The research examines how alcohol and cigarette consumption, career path, future employment, and overall physical health impact satisfaction. The purpose of the study was to determine the extent to which each of these factors affects the life satisfaction of engineering students in Serbia, as well as to assess the overall satisfaction with current life among the youth. The study also aims to identify significant differences among students who vary in their GPA as well as between male and female respondents. To evaluate significant differences among the variables measured, statistical tests such as Mann-Whitney and Kruskal-Wallis were employed. Bonferroni correction was also used as a post-test to compare three or more groups. Significant differences between male (n = 181) and female students (n = 224) were found, predominantly in social factors as well as in family life and friendships. Students who achieved higher academic success showed increased satisfaction with family, social life and their overall life. Moreover, students receiving financial support exhibited greater satisfaction with their university experience and overall life.

Keywords: youth; life satisfaction; employment; career path; smoking; alcohol consumption

Examining the Role of Race, Gender, and Major in Engineering Major Selection Through Ecological Systems Theory Perspective 678–701
Sinan Onal and Ezra Temko

In U.S. higher education institutions, there's an increasing focus on attracting more students, especially minorities and underrepresented groups, to engineering majors. Despite existing research on factors influencing engineering major choices, the specific roles of demographics, such as gender and race, remain crucial for enhancing diversity and inclusivity in engineering

departments. This study investigates how and when undergraduate engineering students prioritize various factors in selecting their majors, with a particular focus on differences across gender, race, and specific majors. Utilizing Ecological Systems Theory (EST) as a framework, the study analyzes responses from 276 engineering students at a public university in the Midwest during the 2022/2023 academic year, employing methods like crosstabs, chi-square, t-tests, ANOVA, and regression analyses. Results indicate that students' priorities align with EST systems, considering aspects like salary, influence from family and friends, and guidance from advisors and professors, as well as the importance of hands-on projects. Notable variations are observed among demographic groups: White, Female/Genderqueer (FGQ) students, and those in Industrial Engineering (IE), Construction Management (CM), and Mechatronics and Robotics Engineering (MRE) majors emphasize salary, while American Asian or Pacific Islander (AAPI) students value hands-on projects more. Additionally, FGQ students find advisors more influential, whereas AAPI students lean more towards professors. These findings highlight the necessity for tailored support mechanisms in engineering schools, particularly addressing the unique challenges and needs of FGQ, AAPI, and Students of Color (SOC) students, and emphasize the importance of personalized guidance to facilitate informed major selection.

Keywords: engineering education; major choice; decision-making; ecological systems theory; race and gender