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Mentorship**

Editorial

703

*Ahmad Ibrahim***Integrating an Expanded Set of Reference Types into Engineering Writing**

704–714

Thomas K. Gaylord, Sushant Guha and O. Joseph Ibiyemi

Engineering student writers must document their reference sources in their theses, papers, proposals, reports, and related documents that they prepare. This is generally done in Microsoft Word or in a LaTeX software package and typically done in the IEEE citation style which is widely used in engineering and technology. In this work, we identify 25 primary reference types and 21 secondary reference types that are used in present-day engineering writing. Because all 46 of these engineering reference types are typically not available in commercial reference management software, we have generated customization files for the widely used EndNote reference management software package that enable referencing to be done using either Cite-While-You-Write (CWYW) for Word users or using BibTeX for LaTeX users. These customization files and instructions on how to install and use them, herein called the Georgia Tech Engineering Reference Management System (GTERMS), are made available on an open-access free-to-use basis.

Keywords: Engineering writing; reference types; reference management

Exploring High School Engineering Students' Integration of Biological Concepts in the Engineering Design Process

715–732

Abeera P. Rehmat, Meltem Alemdar, Michael E. Helms, Roxanne Moore and Marc J. Weissburg

Biologically inspired design (BID) in engineering is a systematic approach that employs analogies from biological creatures to develop solutions for engineering problems. BID is becoming increasingly prevalent in pre-college education as it facilitates students' understanding of how natural systems and features can inspire the design of systems to solve societal problems. This qualitative descriptive study investigated high school students' ($n = 53$) use of biological systems, processes, and concepts covered in the BID-integrated engineering-focused curriculum in the engineering design process (EDP) to develop a solution to the engineering problem. The EDP is an iterative method employed by engineers for effective problem-solving which students employed to create a better food delivery system for senior citizens. Several data sources were used to examine students' application of BID-integrated EDP, including classroom observation field notes, final design presentations, and semi-structured focus groups. Qualitative thematic analysis revealed four major themes: *criteria/constraints, integration of biologically inspired design in the engineering design process, decision-making, and internalizing of structure, function, and mechanism*, demonstrating that students engaged in the engineering design process holistically and iteratively and incorporated features of biological systems in their design solutions.

Keywords: engineering education; biologically inspired design; K-12 education; design-based learning

The Impact of Different Levels of Cognitive Questions in Examination Papers on the Final Grades of First-year Electrical Engineering Students

733–740

Arthur James Swart and Danri Delpont

Examination papers are used around the globe as assessments for learning, as learning and of learning. Many academics seek to maintain a balance between lower order and higher order cognitive questions in these papers, seeking to help students transform their knowledge from quantitative to qualitative in nature. Some achieve this by using different illustrative verbs from the six levels of Bloom's Taxonomy. The purpose of this research is to investigate the degree to which different levels of questions in a summative examination predict the final grade of two types of students in a compulsory electrical engineering module. These two groups are termed ECP students (students who undertake an additional year of study prior to enrolling in a mainstream programme) and MSP students (students who enroll for a mainstream programme directly after completing their high-school career). Stepwise regression was used to analyze the data ($n = 64$ for the ECP group and $n = 487$ for the MSP group from 2016 and 2017) to find a set of independent variables (individual questions in the summative examination) that significantly influence the dependent variable (final grade of the summative examination). Results indicate that, on average, three out of six questions contributed the most to the final grades of the ECP students while all six questions were found to contribute for MSP students. A key deficiency in ECP students was noted regarding applied mathematics required in the analysis and design of electrical circuits. A possible recommendation is to expose ECP students to more physical science questions that require several different equations during their additional year of study to better help them demonstrate important higher-order cognitive skills.

Keywords: freshmen; Extended Curriculum Programme; Mainstream Programme; Bloom's Taxonomy

Assessing Engineering Doctoral Students' Experiences in Chinese Institutions

741–756

Xiaoqing Xu, Guandong Song and Ying Yang

Training objectives stand as pivotal elements in shaping the academic trajectory of academic engineering doctoral students (AEDS), exerting significant influence on their academic orientations and professional competencies. This study employs a synthesis of qualitative grounded theory and quantitative research, drawing insights from the perceived experiences of AEDS, to scrutinize the rationality of current training objective configurations. A dual-track analytical framework is constructed, encompassing two distinct studies. The first study utilizes grounded theory to analyze training objectives from 144 Chinese educational institutions. The second study designs a questionnaire to assess AEDS's perceived training quality, establishing a path analysis model to validate hypotheses. Results from the first study delineate a comprehensive framework for training objectives, encompassing dimensions

such as thought and behavior, research accumulation, research literacy, research belief, research level, and research performance. Notably, relevant disciplinary knowledge and scientific awareness are found to receive inadequate attention. In the second study, all hypotheses are validated, indicating the overall reasonability of current training objectives. However, contradictory results emerge regarding relevant disciplinary knowledge and scientific awareness. Path analysis underscores the significance of relevant disciplinary knowledge and scientific awareness, implying that institutions should intensify investments in cultivating these aspects to elevate the training quality of AEDS.

Keywords: training objectives; engineering doctoral students; grounded theory; students' experience

Conjecture Maps as a Cognitive Tool for Connecting Engineering Education Research and Practice

757–775

Alejandra J. Magana

The study proposes an approach for using conjecture mapping as a cognitive tool to overcome conceptual difficulties among novice discipline-based education researchers, including framing research questions, grounding studies in frameworks, and operationalizing constructs into measurements. The research question was: What are novice researchers' perceptions and experiences of conjecture mapping as an approach to guide their investigations? A Phenomenographic approach was used to analyze participants' perceptions and experiences of conjecture mapping. The participants consisted of eleven engineering and computing education researchers in the early stages of their graduate education. The participants learned about conjecture mapping and used it throughout the semester to propose learning and research designs. The participants reflected on their experiences. Five categories of description were identified, describing participants' perceptions of the affordances of conjecture mapping. Those categories of description were further organized into an outcome space describing more comprehensive ways of experiencing conjecture mapping, along with two dimensions of variation. This study contributes new knowledge that builds on the structure of conjecture mapping into specifics of a process of socialization and deployment with a population of novice researchers. The approach showed promise in overcoming some of the most pressing conceptual difficulties experienced by computer scientists and engineering novices in learning educational research methods.

Keywords: conjecture mapping; discipline-based education research; design-based research; phenomenography; qualitative methods

Assessment of the Effect of Attitudes of Information Engineering Students on Academic Misconduct

776–787

Liu Xin Juan and Zhang Bin

The technological innovation of open artificial intelligence (AI) brings more free and convenient resources for university students, and Information Engineering (IE) students have priority skills to enjoy, which may challenge their honest behavior. This study is one of the few cross-institution empirical studies in the Chinese context and 447 IE samples from five public universities are included in the quantitative research to investigate the effects of attitude, and intention on behavior toward academic misconduct (AM). The structural equation modeling technique was used to test the developed hypotheses, bootstrapping, and confidence intervals to test the mediating effect. It demonstrated that attitude was a significant predictive variable of intention and intention had a statistically significant effect on AM behavior, in which, the effect of attitudes factor on IE students' engagement in AM behavior was mediated by intention. Pre-event educational intervention, monitoring AI technical support, and post-violation punishment are essential to help engineering students establish correct attitudes to resist the temptation of AM behavior and promote the sustainable development of engineering education.

Keywords: attitude; academic misconduct behavior; IE students; open AI

An OBE-CDIO Closed-loop Teaching Model to Advance the Quality of Instruction in an Internet of Things Program

788–800

Jiawen Li, Xinyu Wu, Xindi Zhang, Qiong Nie, Min Yang, Qiqiao Li, Huimin Zhao, Jinchang Ren and Rongjun Chen

Regarding the contemporary economic trend marked by emerging technologies, novel industries, evolving formats, and innovative modes, engineering education on the Internet of Things (IoT) should actively respond to challenges and align with global development strategies. To this end, this work proposes a closed-loop teaching model based on OBE-CDIO to resolve the main issues in this field, including the incongruities between teaching content and industry demands, fragmented curriculum provisions, and limitations on students' technical capabilities. In this closed-loop teaching model, the instructional design is guided by Outcome-Based Education (OBE), and the curriculum implementation is based on Conceive-Design-Implement-Operate (CDIO). Besides, to further enhance the quality of instruction for better cultivating high-quality students, the model can iteratively adjust the teaching design based on feedback. The method validation is performed by administering questionnaires, tests, and controlled experiments to 40 students in terms of their attitudes, knowledge, and abilities. The results demonstrate that the proposed model beneficially advances the quality of teaching and enhances the student's skills. Particularly, the average score for the experimental class is 87%, whereas the traditional class attains an average score of 52.5%. Consequently, it can be concluded that the model significantly contributes to fostering teaching innovation in an IoT program. Such experiences provide insightful reference cases for developing and implementing IoT-related courses.

Keywords: outcome-based education (OBE); conceive-design-implement-operate (CDIO); internet of things (IoT); teaching model

A Digital Tool for Scaffolding Innovation Learning in Engineering Education with Local Industry Needs

801–814

Kamila Kunrath, Serena Leka, Lasse Steenbock Vestergaard, Mirko Presser and Devarajan Ramanujan

Providing students with the knowledge, skills, and competencies in innovation has become a central focus in engineering education. However, there is limited knowledge on which innovation skills must be supported to reduce the current knowledge gaps between universities and industry. Furthermore, there has been limited investigation into the role of digital solutions that can promote innovation education and the acquisition of industry-relevant innovation skills in engineering curricula. To this end, this paper explores the use of industry challenges (via case studies) as a resource that students and educators can use for targeted ideation and solutions development in teaching. We examined 78 innovation cases provided by local industries for two mandatory master-level courses on innovation at a Danish university. We identified dominant trends from the case descriptions that express areas of interest and demands from different industry sectors. Based on these findings, we have developed an interactive digital tool to support course instructors in increasing the accessibility and utility of industry-defined innovation cases in student-led ideation activities.

Keywords: sustainability; engineering education; industry; innovation

Exploring the Academic Paths and Professional Aspirations of GenZ STEM Students in the Canary Islands

815–832

C. Sierra, C. Boente, R. Baelo, L. Estévez and E. Rosales-Asensio

Characterized as the generation most comfortable with technology and social media, Generation Z (Gen-Z), people born from the mid to late 1990s into the early 2010s, are the most recent entrants to the workforce and to date their perceptions towards continuing education, their employability and future job prospects are still under research. To address this aspect, we gathered a corpus (N = 124) of Gen-Z bachelor students in the Canary Islands (Spain) and used a questionnaire to interrogate them. An

educational system that best prepares students for current market needs not only benefits industry but also students' perception of their own employability. The motivation for this work then, lies in the extensive research identifying a potential gap between graduates' skills set and the requirements of various industries. Our findings underscore the significance of fostering students' employability skills poorly addressed by traditional teaching methods. Additionally, our data indicates that good social networks notably improve students' resilience and increase levels of optimism concerning their future career opportunities. These findings have far-reaching implications for the development of educational strategies and recruitment approaches that will more effectively integrate graduates into the evolving workforce.

Keywords: tertiary education; personal satisfaction; career choices

How Inclusiveness of Learning Environment Mediates the Evolution of Engineering Students' Motivational Beliefs in a Two-Semester Introductory Physics Course Sequence 833–850

Yanqiuqing Li and Chandralekha Singh

In this study, we focus on engineering students' motivational beliefs and course grades in a two-term college calculus-based introductory physics sequence (physics 1 and physics 2). We investigated how engineering students' perception of the inclusiveness of the learning environment (including their sense of belonging, perceived effectiveness of peer interaction and perceived recognition) predicts their physics course grades and motivational beliefs including self-efficacy, interest, overall physics identity, and overall engineering identity. Using structural equation modeling, we find that students' perception of the inclusiveness of the learning environment statistically significantly predicts their physics grades and motivational beliefs. In particular, students' engineering identity is statistically significantly predicted by engineering students' perception of how they were recognized as a physics person. In addition, we find that the gender differences in students' physics self-efficacy, interest, overall identity, and grades were partially mediated by the different components of students' perception of the inclusiveness of the learning environment. Our findings suggest that instructors' focus on equity and inclusion, and approaches to student recognition, are especially important for supporting students' engineering identity and promoting learning for all students in the classroom.

Keywords: equity; gender; identity; learning environment

The Impact of Design Thinking, Maker Education, and Project-Based Learning on Self-Efficacy of Engineering Undergraduates 851–862

Patricia Santos, Miriam Calvera-Isabal, Amaia Rodríguez and Khadija El Aadmi

Engineering programs in higher education have traditionally focused on technical skills, but there is a need for engineers to develop additional skills such as experimental, making, and design. Design thinking practices are increasingly seen as crucial components of the engineering curriculum. The purpose of this study is to investigate whether integrating project-based learning with Design Thinking and Maker tools can enhance engineering students' self-efficacy. Given the underrepresentation of women in engineering and past findings on gender differences in making skills, the study also aims to analyze the impact of these educational practices from a gender perspective. This research was conducted over two years with undergraduate engineering students in a real educational setting. It assessed changes in students' engineering self-efficacy before and after a project-based learning activity that utilized Design Thinking and Maker Education to address real-world problems. The study involved 67 students (45 men, 21 women, and 1 who preferred not to say) and employed a comparative analysis of data collected pre- and post-intervention. The study found significant differences in self-efficacy between male and female students prior to the intervention. After participating in the project-based learning activity, students reported an increase in self-efficacy, with women showing a notable improvement in making skills. The findings suggest that project-based learning activities that incorporate Design Thinking and Maker Education can positively influence engineering students' self-efficacy. The impact appears to be particularly beneficial for women students, indicating that such educational approaches may help address gender disparities in engineering disciplines.

Keywords: Design Thinking; Maker Education; Project-based Learning; engineering

Evaluating the Impact of ChatGPT on Programming Learning Outcomes in a Big Data Course 863–872

Patricia Callejo, Carlos Alario-Hoyos and Carlos Delgado-Kloos

Recent advances in Generative Artificial Intelligence are leading to major changes in education, both in the way educators teach and in the way students learn. For example, Generative Artificial Intelligence (GenAI) chatbots, such as ChatGPT, can help students by assisting them in problem solving or supporting them in code development tasks. This article aims precisely to explore the effect of ChatGPT in supporting students with different levels of programming experience in a course on Big Data. A Big Data challenge was carried out during one of the sessions with 31 students from different backgrounds. Overall, the students were able to solve the challenge, and the results of the pre- and post-tests indicate that the students improved their grades, i.e. they learned to solve the programming exercise. This quasi-experimental study shows that ChatGPT can be a valuable tool as an assistant in the field of data science and programming for students learning to program (even for the first time), whether they come from engineering programs or other completely different disciplines. It is important not to forget the role of the professor in guiding the students towards the correct use of these GenAI tools.

Keywords: Generative Artificial Intelligence; ChatGPT; Programming; Python; PySpark; Big Data

Investigating the Impact of Learners' Time Allocation in Immersive Simulation-Based Learning Environments 873–887

Mahgol Nowparvar, Noah Soriano, Sabahattin G. Ozden, Parhum Delgoshaei, Omar Ashour and Ashkan Negahban

With the increasing use of virtual simulated environments and immersive technologies in STEM education and workforce training, it is becoming increasingly important to study and understand how learners' interactions and navigation in virtual environments affect their learning and skill development. In this paper, we quantify and assess the effect of learners' navigation in an immersive simulated environment on learning outcomes, where navigation is characterized by the total time spent in the simulation and time allocations to different areas within the virtual environment. We implement a set of immersive simulation-based learning (ISBL) modules in an undergraduate computer science course with eighteen students and record their screen as they navigate in the simulation environment to perform the tasks needed to complete the ISBL assignments. We use a video analytics tool to process and analyze the videos and collect statistics related to a set of navigation-related measures for each student. We also use surveys to collect data on students' demographics, prior knowledge and experience, personality, experiential learning, and self-assessment of learning. We then perform a set of multivariable regression analyses to characterize and explain the relationship between navigation measures and constructs assessed via survey instruments to determine how/if users' navigation in the simulated environment can be a predictor of their learning outcomes. The results indicate that the total time spent in the simulation and the distribution of time allocations among different areas within the simulated environment are predictors of experiential learning and students' self-assessment of learning.

Keywords: simulation-based learning; immersive technologies; human-computer interaction; video analytics

Chin-Wen Liao, Kai-Chao Yao, Sheng-Chieh Nien, Chun-Chung Liao, Hui-Ching Nien, Wei-Lun Huang, Yu-Chien Shih, Wei-Sho Ho, Ying-Ju Tseng and Yu-Yuan Ko

This study investigated the challenges and coping strategies of online teaching among vocational educators in Taiwan, focusing on the electronics and electrical engineering sectors. Employing stratified random sampling, a questionnaire survey was conducted across 20 schools, garnering 376 valid responses out of 486 distributed, reflecting a 77.36% response rate. Analysis methods included descriptive statistics, t-tests, ANOVA, Scheffe's post-hoc test, and Pearson correlation. Findings revealed that "Management of Online Classes" posed the greatest challenge, whereas "Problem-Solving in Online Teaching" was the most effective coping strategy. Challenges were more pronounced among female educators, those with a Bachelor's degree, specializing in Control Science, teaching in the southern region, or lacking in self-generated digital resources over the past three years. In contrast, educators with advanced degrees or recent digital teaching development experience aligned more closely with effective coping strategies. A significant correlation was observed between the challenges and coping strategies in online teaching.

Keywords: vocational education; online teaching challenges; online teaching strategies

Utilizing IoT Systems to Improve Students Digital Competency and Awareness of Environmental Issues

916–928

A. Leo-Ramírez, J. Álvarez and C. Gilarranz-Casado

This research delves into the potential of Internet of Things (IoT) systems to cultivate environmental consciousness among university students across diverse engineering disciplines. The study unfolds in two distinct phases. In the initial phase, we assess students' (between 30–40 depending on the session) environmental awareness across four dimensions outlined in the existing literature: awareness of environmental issues, awareness of individual responsibility, general attitudes toward environmental solutions, and general attitudes toward environmental issues. Our observations reveal a moderate overall level of environmental consciousness among students, with some variability in responses based on the dimension assessed. Subsequently, in the second phase, with 18 students, the study employs a Likert scale pretest and posttest, comprising five levels, to gauge the impact of the IoT system on three dimensions: enhancement of students' digital competences, improvement of IoT skills, and cultivation of environmental awareness. Overall, our findings suggest that the IoT system utilized in the experiment positively influences the enhancement of students' digital competences and IoT skills. However, the perceived effectiveness in cultivating environmental awareness exhibits a more modest increase with less uniformity in the responses. These results underscore the nuanced influence of IoT systems on different facets of student learning and highlight the importance of considering multidimensional outcomes when integrating such technologies into educational settings. The study contributes valuable insights for educators seeking to leverage IoT applications to not only advance technical skills but also foster a holistic understanding of environmental issues among future engineering professionals.

Keywords: IoT; Environmental awareness; digital competences; IoT skills; educational technology

Leadership in Interdisciplinary Engineering Students' Projects: A Faculty Perspective for Supporting the Development of Student Leadership

929–947

Henrik Worm Routhé, Jette Egelund Holgaard and Anette Kolmos

Engineers in the 21st century will be confronted with complex problems that require new competences to engage and collaborate with other disciplines. New engineering competences, such as leadership across interdisciplinary contexts, necessitate important changes in engineering education. To make such changes possible, however, the development of educational leadership is needed, including the creation of organizational structures and the training of staff to support the development of student leadership skills. This leads to the following research question: What kind of leadership can be identified in interdisciplinary student projects from a faculty perspective, and in which way can the development of students' leadership competences be supported? A model is introduced for different leadership concepts at both the faculty and the student levels. The research, comprising three different subcases, is based on data from 12 semi-structured interviews with members of the staff at the Faculty of Engineering and Science and the Technical Faculty for IT and Design at Aalborg University, where student teams work together on solving complex problems. The interview data was transcribed and coded in NVivo using thematic analysis. Findings illustrate the complexity of leadership involved in the student projects, in which teams collaborated with teams, supporting the leadership model introduced in this research, where examples of shared leadership, emergent leadership and rotating leadership were identified at the students' level. Educational leadership – reflected here in curricular structure, learning objectives, and projects as well as facilitation – is important for supporting the development of students' leadership competences.

Keywords: leadership; interdisciplinarity; engineering education; problem-based learning

Analysis of A Systematic Literature Review of Engineering Identity Research (2005–2019)

948–964

Shawna Fletcher and Kristi J. Shryock

Since 2005, engineering identity models have emerged within the literature. This publication further examines a systematic literature review conducted to conceptualize engineering identity theory by two independent researchers. The systematic literature review uncovered undergraduate student research, especially underrepresented populations, in higher education between 2005–2019. This analysis explores the origins of engineering identity theory and identity models used in its evolution. This analysis contains an in-depth examination of 43 sources and a detailed explanation of the scope, methods, and categorizations provided in the previous publication. Authors concluded that research on engineering identity can improve by (1) adopting uniformity across terms and factors that are easily identified; (2) recognizing, understanding, and building upon the depth and breadth of research in disciplines other than engineering; (3) correlating engineering identity factors with student success and retention; (4) designing valid measurement instruments specific to engineering identity; and (5) incorporating standards for robust measures, including control or comparison groups. Gaps in literature and future research recommendations are discussed.

Keywords: analysis; systematic literature review; engineering identity; engineering identity research; women in engineering; under-represented populations; quick reference guide

Bridging Sustainability and Physics: Fostering Inclusion and Awareness of SDGs in Engineering Curriculum

965–978

Daniel Tarrazó-Serrano, César González-Pavón, Sergio Castiñeira-Ibáñez, Patricia Arizo-García, Antonio Uris and Constanza Rubio

This study evaluates the integration of the Sustainable Development Goals (SDGs), focusing on SDG 13 (Climate Action), in higher education and its impact on students' awareness and knowledge at the Universitat Politècnica de València. Given the urgency of addressing climate change and its repercussions, the research highlights the pivotal role of education in fostering understanding and engagement with the SDGs, particularly among engineering students. The study utilized pre- and post-awareness session surveys to assess the prior knowledge and subsequent learning progression concerning SDGs among students from the School of Telecommunications Engineering and the School of Agricultural Engineering and Environment. Results indicate a

significant knowledge gap, with over 60% of students unaware of the SDGs. However, following targeted educational interventions, a marked increase in SDG comprehension and interest was observed, particularly among students from the agricultural and environmental engineering school, reflecting disciplinary influence on sustainability receptivity. Gender differences emerged, with women more aware of climate change's present effects while men expressed greater interest in future-related issues. Older students demonstrated better content assimilation, and public education students showed higher SDG awareness than those from private institutions. The study underscores the necessity for personalized education strategies and a revised approach to integrating SDGs into curricula and research projects to enhance the effectiveness of sustainability education in preparing future professionals to contribute to global sustainability challenges.

Keywords: Physics; SGDs; challenge learning; problem-based learning; meaningful learning

Fostering Soft Skills through Cross-disciplinary Robotics Mentorship

979–992

Wenyan Huang, Ping-Chuan Wang, Graham Werner and Scot Sutherland

Success in the professional engineering workplace increasingly requires soft skills in addition to technical knowledge. Faculty and curriculum constraints present higher education with significant challenges for fostering soft skills in engineering students. This paper provides an overview of an interdisciplinary model, involving undergraduate engineering students and mathematics teacher candidates, to co-design STEM-related workshops for a high school robotic club in an after-school mentoring program. Drawing on questionnaire and interview data from the 25 mentors across three years, we elaborate on the model's effectiveness through the lens of soft skills development. We share the journey of how these mentors collaborate and interact with their cross-disciplinary colleagues and serve as mentors for high school students. We then report empirical evidence on how the social interaction embedded in our design model enhances the engineering and education mentors' soft skill development in *Teamwork*, *Presentation*, *Leadership*, and *Adaptability* skills. We also discuss the implications and recommendations for further research based on our findings.

Keywords: soft skills; engineering education; interdisciplinary; higher education; mentorship

Book Review

993–995

Having A Teaching Mentor on Your Bookshelf – A Review of *Teaching and Learning STEM: A Practical Guide* (second edition)

Milo D. Koretsky & Lorena S. Grundy

Guide for Authors

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