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Selective plating serves as a method for locally repairing structural components, offering practicality as technical engineers can apply it directly on-site. However, proper training is essential for operators to perform this process effectively. Mastery of the technique can take months and involves significant chemical and financial expenditures. Recognizing these challenges, virtual reality has emerged as a promising solution for cost-effective training. This study aims to explore the potential of virtual reality in surface manufacturing training and develop a selective plating training program. It was carried out by a group of M-level engineering students. The methodology comprised three phases: exploration, development, and improvement. In the exploration phase, knowledge about both virtual reality and selective plating was gathered. The development phase involved creating a prototype training scenario through collaboration with an industrial expert. Finally, in the improvement phase, 41 engineers in training from diverse backgrounds tried and assessed the educational training, identifying strengths, weaknesses, and potential future improvements. The selective plating training was divided into three parts: a main menu, a learning scenario to familiarize users with functions and controllers, and the selective plating training scenario simulating the deposition of cadmium onto an aircraft landing gear. Positive feedback regarding the benefits of the technical training was received, and suggestions for further enhancements were proposed.  
*Keywords:* aerospace; simulation; programming; education; surface repair
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*Hernán D. Sánchez-Restrepo, Cristian A. Hernández-Salazar and Octavio A. González-Estrada*  
This materials laboratory proposal for undergraduate students focuses on the analysis and optimization of the mechanical properties of continuous fiber-reinforced thermoplastic composites using additive manufacturing. Additive manufacturing is a versatile and useful manufacturing process for complex parts for which using traditional methods would be difficult or impossible to manufacture. Experimental data from mechanical tests, tensile strength, and fatigue will be investigated to characterize these compounds, using nylon as a matrix and different filling patterns and types of reinforcing fibers. Machine Learning will be applied to develop regressions and predict the mechanical behavior of compounds under different process parameters. The results show that machine learning models can accurately predict composite fatigue and have the potential for the design and optimization of composite materials manufactured by additive manufacturing. This lab will provide students with hands-on experience in material characterization, additive manufacturing, and the use of Machine Learning, contributing to the advancement in the field of materials and additive manufacturing for demanding engineering applications.  
*Keywords:* mechanics of materials; fused deposition; reinforced thermoplastic composites; fatigue; artificial intelligence
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*Matthew Bahnson, Monique Ross and Catherine G. P. Berdanier*  
Postdoctoral training holds an increasingly important position in securing high-impact research and academic positions in engineering and computer science. High-quality mentorship contributes to the success of postdoctoral trainees, but existing literature demonstrates postdocs from outside of the US, women, and racial minorities who experience stereotypes are provided less mentorship, and less successful outcomes than their white and male counterparts. Further, trainees who originate from outside of the US hold more than half of the postdoctoral positions in the US. Increasingly, funding agencies within the US require postdoctoral mentorship plans, but it is unclear to what end and if they are helpful or simply performative. Specifically, to date, no research has investigated the content of mentorship plans, their alignment to theory and existing research, or the needs of postdoctoral trainees particularly those from outside of the US, women, and racial minorities. As part of a larger project investigating postdoctoral mentorship, we analyzed 54 postdoctoral mentoring plans to identify how they align with recommendations from content supported by theory and literature. We find marginal alignment with best practices, with much room for improvement, including tailoring and specificity. From this work, a postdoctoral mentorship blueprint and rubric for plan evaluation are offered as tools to improve the uniqueness, specificity, and utility of mentorship plans.  
*Keywords:* postdoctoral; mentorship; content analysis; engineering; computer science
- Instructional Strategy for Delivering Building Information Modeling Literacy** 34–46  
*Ag Tamrin, Anis Rahmawati, Taufiq Lilo Adisucipto, Wahyu Noviansyah and Asnul Dahar Minghat*  
The study aims to develop and examine the Project-Building Information Modeling (Pro-BIM) instructional strategy in improving BIM literacy for students in the fields of architecture, engineering, and construction. The participants consisted of two industrial BIM practitioners, two CEE instructors and 28 students enrolled in designed course were selected purposively for convenient sampling. This study adopted Design-Based Research (DBR) method. Data collection techniques included: (1) observation, (2) interview, (3) FGD, (4) test, and (5) documentation. Qualitative data analysis techniques were data collection, data presentation, and conclusion while quantitative data analysis techniques included descriptive analysis. The results indicated that: (1) analysis and exploration were literature review, design analysis, cost, and sustainability, (2) design and construction included six steps of Pro-BIM and the increasing of student's BIM literacy, and (3) evaluation and reflection included FGDs producing positive perceptions of students, lecturers, and educational practitioners. This study concludes that the Pro-BIM learning strategy is effective in

improving BIM literacy among AEC students through the integration of BIM technology into relevant courses. The study indicates that the integration of Pro-BIM learning strategies into the AEC higher education curriculum improves student's understanding and skills in applying BIM technology.

*Keywords:* project-building information modeling (PRO-BIM); building information modeling literacy; instructional strategy; project-based learning; design-based study

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*Thomas R. Tretter, Catherine L. Biesecker, Brian S. Robinson, Fei Bi Chan, Angela K. Thompson and Jessica B. Buckley*

The COVID-19 pandemic caused numerous universities to conduct classes in Fall 2020 in remote formats, which may impact student's sense of belonging differently depending on their identity, especially since belonging is a construct largely comprised of feelings of social connectedness. This study explored how underrepresented groups in first-year engineering perceived their sense of belonging during these involuntary remote/hybrid courses. Quantitative data from a survey administered to the COVID cohort were compared to 3 prior pre-COVID cohorts to investigate COVID impacts, supplemented by several open-ended questions. Results showed that female engineering students had a significantly lower sense of belonging during COVID than their counterparts, and reported significantly more negative social experiences than men. Sense of belonging and positive/negative social experiences did not differ for students of different race or income, but the trending patterns suggested that there may have been differences that our measurements were not sensitive enough to fully capture. The online COVID experience also decreased the gap in sense of belonging between high- and low-income engineering students by diminishing sense of belonging for students from a high-income background compared to pre-COVID years.

*Keywords:* sense of belonging; first year engineering; COVID hybrid course; undergraduate students; social experiences

**Trends in Research on Scientific Discourse and Argumentation Published by European Conference on Research in Science Education (ESERA) through 2011–2021: A Systematic Analysis** 62–74

*Yousef F. Alfarraj and Abdulwali H Aldahmash*

The Next Generation Science Standards (NGSS), Standards for K-12 Engineering Education, A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas, the National Center for Assessment in Higher Education (QIYAS) and the Saudi Council of Engineers (SCE), and Standards for Technological and Engineering Literacy (STEL) emphasize the importance of scientific discourse and argumentation in student learning, particularly through the scientific and engineering practices of engaging in argument from evidence. This paper analyzes trends in scientific argumentation research by reviewing studies from the ESERA conference proceedings between 2011 and 2021 using quantitative and qualitative approaches. The findings reveal that articles on argumentation and discourse constituted 3.8% to 6.6% of total publications, peaking at 6.6% in 2017. While no consistent patterns emerged in keyword usage, common themes included classroom discourse, argumentation, context, and learning processes. Over 60% of the articles focused on topics such as discourse analysis and student understanding, with qualitative methods dominating, accounting for about 75% of the studies. These results highlight the increasing significance of research in discourse and argumentation, aligning with contemporary trends emphasizing evidence-based practices, and suggest a continuing need to prioritize argumentation in science, technology, engineering, and mathematics (STEM) education to enhance student engagement and comprehension.

*Keywords:* argumentation; scientific discourse; science education; research trends; engineering education; systematic analysis

**Undergraduate Student Views on Social Innovation in Engineering** 75–87

*Ekundayo Shittu, Tiffany-Rose Sikorski, Erica Wortham, Upmanyu Singh and Jason Starita*

Social innovation is an approach to problem solving and design that focuses on increasing social value and minimizing suffering of marginalized groups. We report on a three-year effort to establish social innovation as a core professional competency among a small group of undergraduate engineers who are passionate about social justice issues. In this illustrative case study, multiple data sources are analyzed to understand the extent to which students view social innovation as accountable disciplinary knowledge for their future careers as engineers. Students perceived that engineers should make connections between their work and society by (1) identifying issues that cause marginalization, (2) working with communities experiencing marginalization in designing solutions, and (3) understanding policy. These findings indicate that exposure to social innovation could provide undergraduates an important opportunity to re-evaluate the knowledge required for professional engineers to have a positive impact on society.

*Keywords:* social innovation; social entrepreneurship; human-centered design

**Examining the Engineering Gender Gap through a Correlation of Childhood Toys and Activities with Engineering Persistence** 88–102

*Anastasia M. Schauer, Nathaniel S. H. DeVol and Katherine Fu*

The reasons for the lack of gender diversity in computer science and engineering (CS&E) fields are nebulous, and past research has shown that disparities in spatial skills that predict pursuit of CS&E careers begin to develop in childhood. Because playing with spatial toys in childhood has been correlated with higher spatial skills, childhood toys have been hypothesized to influence career choice. To investigate correlations between childhood toy usage and career choice of adults, 960 participants were surveyed to collect information on career choice and retrospective childhood toy usage. When controlling for gender, there was not a significant correlation between playing with spatial toys and working in a CS&E career, in part due to the strong gender-stereotyping of both spatial toys and CS&E careers as masculine. The prevalence of masculine-stereotyped spatial toys highlights the importance of targeting K-12 STEM intervention and outreach toward a diverse range of students. From the gender-stereotype perspective, a significant correlation was found between women who played with more masculine-stereotyped toys as a child and women who do not work in feminine-stereotyped career fields, indicating a correlation between breaking gender stereotypes in toy usage as a girl and career selection as a woman. These findings justify the need for inclusivity in the marketing of toys and STEM outreach, as well as encouragement of breaking gender stereotypes in childhood play by parents and educators.

*Keywords:* gender stereotypes; CS&E career choice; K-12 outreach; toys; gender gap

**Effective Teaching Method on Impedance Spectrum of Electrochemical Cell using Microsoft Excel for Beginners in Electrochemistry** 103–112

*Hyung-Gun Kim, Jeongyeon Ryu and Cheolsoo Jung*

This study examined an impedance learning methodology applicable to electrochemical cells using Microsoft (MS) Excel Software. MS Excel, a tool commonly used by practitioners in chemical engineering, can provide an educational platform for analysing and understanding the complex impedance characteristics of electrochemical cells. The impedance learning method using MS Excel aims to increase the efficiency of impedance education by providing a user-friendly interface for beginners and experts in electrochemistry. This paper proposes using the MS Excel functions to simplify data input, processing, and interpretation for each component within the various impedance circuit patterns in electrochemical cells. This information caters to students aspiring to engage in the research and development of next-generation electrochemical cells, serving as an educational resource for grasping the concept of impedance with ease. This study will also be helpful to researchers in various application fields, including the development of electrochemical sensors and energy storage systems.

*Keywords:* impedance learning; electrochemical cell; Microsoft Excel; simulation

Occupational safety and health training is the foundation of preventive protection at work. The training process aims to equip and empower workers with the necessary skills and knowledge to perform their tasks safely. This paper presents a training model developed using virtual technology (VR) with a 360-degree (image or video) display. The model is designed and implemented for the position of a CNC operator. The model integrates procedures for initial work process training and training for occupational safety and health at the workplace. Based on the developed model, research was conducted on the possibilities of improving the overall training process. The research was carried out on two samples: the first sample consisted of students in the final grades of secondary school for the occupation of CNC technician, and the second sample consisted of workers with experience in working with CNC machines. The research results showed that this occupational safety and health training model for is faster, simpler, more mobile, and of higher quality than the current traditional approach.

*Keywords:* advanced training model; occupational safety and health; virtual technologies; CNC operator

Assessing Entrepreneurial Mindset (EM) is recognized as a challenge within the engineering education field. Concept maps (cmaps) show promise for direct assessment of EM development, but manual scoring of cmaps is time-consuming and subjective, highlighting the need for automated scoring tools to alleviate these drawbacks. Yet, automated tools for categorical scoring – an approach combining quantitative and qualitative metrics – are lacking. To address this gap, we developed the Semi-Automated Scoring Tool (S-AST) and conducted a study involving five faculty members to evaluate S-AST. Participants engaged in manual and S-AST-assisted categorical scoring sessions, followed by interviews with the research team. The research aimed to determine the extent to which S-AST facilitates categorical scoring and to identify areas for further improvement of the tool to better meet faculty needs. Results underscore the potential of S-AST in streamlining EM cmap assessments and highlights areas for improvement, such as enhancing the user interface for better navigation and clarity, improving explanations in the results file, and providing a visual representation of the cmap to increase faculty members' confidence in category assignment.

*Keywords:* concept maps; assessment tool; categorical scoring; educational technology

Understanding students' language needs is key to maintaining sustainability in English medium instruction (EMI) higher education programmes. Though increasing research has been published on EMI practices worldwide, these practices remain under-explored in science, technology, engineering, and mathematics (STEM) higher education programmes in some international contexts. In this study, we combined questionnaire and interview data to explore Saudi university STEM content teachers' perspectives on their students' language difficulties and needs. A questionnaire with close-ended and open-ended questions was completed by 132 faculty members (104 Arabic-native and 28 non-Arabic-native), whereas semi-structured interviews were conducted with 16 faculty members. The data analysis revealed that the content teachers are generally dissatisfied with their students' English language levels and performance, particularly in the writing and speaking areas and related academic tasks. In their attempts to cope with the students' difficulties, Arabic-native and non-Arabic-native teachers reported using different coping strategies. The suggestions these teachers provided for helping STEM students perform better in their EMI majors relate to reforming four dimensions in language instruction, use and assessment.

*Keywords:* English medium instruction; STEM education; STEM programme evaluation; higher education; Saudi universities

Service-learning and Project-Based Service Learning (PBSL) are recognized as effective pedagogical approaches for fostering both specific and transversal competencies in students. This paper presents a comprehensive framework for implementing PBSL, complemented by an experiential case study from a Master's program in secondary education teacher training. The project aims to integrate technology education, empowering students to design engaging, hands-on projects for secondary school learners, with a particular focus on utilizing the Arduino microcontroller. Emphasizing collaboration among students, faculty, and organizations supporting individuals with Autism Spectrum Disorder (ASD), this initiative fosters a community-oriented learning environment. During the 2022/2023 and 2023/2024 academic years, 18 and 16 students participated, respectively, alongside 2 university professors and 2 organizations. The projects were conducted at the University of A Coruña, Spain.

*Keywords:* arduino; autism; diversity; higher education; project-based learning; service-learning; technology

This paper presents a virtual simulation experiment system for the study of electric vehicle (EV) drive and control. The experiment system was designed with control problems of electric vehicles (EVs) in extreme road conditions. On the basis of the experiment system, comprehensive experiment contents were developed and have been applied to an automatic control course in Electrical Engineering. A survey using a designed questionnaire and a comparison of students' course performance were conducted to study the four research questions: (1) In what ways does the virtual simulation experiment system impact students' study of EV drive and control? (2) Does the virtual simulation experiment system enhance students' autonomous learning? (3) What are students' experience and perception of this virtual simulation learning mode? (4) Can the virtual simulation experiment system improve learning in the automatic control course? The evaluation indicated that the experiment system had a positive impact on students' study of EV drive and control, in terms of consolidating students' mastery of theoretical knowledge and understanding of EV control principle, helping them master EV drive and control strategies, and improving their ability to design an EV control unit. Students' autonomous learning was enhanced, due to the visual and attractive teaching and their interest in autonomous learning. After applying the experiment system into the course, students' performance has been improved in course attendance and grades. It is demonstrated that the virtual simulation experiment system is effective in promoting the study of EV drive and control and autonomous learning, and in improving learning in the automatic control course.

*Keywords:* electric vehicle; drive and control; virtual simulation; automatic control course

In this paper, we present an advanced conceptual framework for integrating Artificial General Intelligence (AGI) into engineering education (Artificial General Intelligence Integration into Engineering Education (AGI<sup>2</sup>E<sup>2</sup>)). Our aim is to harmonize technical skills with intrinsic human qualities, such as creativity and ethical reasoning, essential for the Industry 5.0 landscape. This framework is based on comprehensive literature reviews and empirical data from 916 students and 1127 faculty/staff surveys, analyzed to assess AGI's potential to foster these human-centered qualities. It includes dynamic, interdisciplinary learning environments, personalized educational trajectories, continuous adaptation, and lifelong learning, addressing the ethical issues of AGI application. Building upon a previously published framework by the authors focused on integrating AI into engineering

education, this work advances the field to meet Industry 5.0 demands while fostering holistic, human-centered learning experiences that prepare technically competent engineers equipped with vital interpersonal skills.

*Keywords:* engineering education; artificial intelligence; artificial general intelligence; educational technology; adaptive learning; career development; educational programs; curriculum development; industry 5.0

**The Role of Academic Performance, Knowledge Sharing and Participation in Academic Activities in Enhancing Student Life Satisfaction and Reducing Academic Burnout** 195–208

*Sonja Ivančević, Marko Mihić and Milica Maričić*

The study endeavors to examine the antecedents and outcomes of university students' academic performance by linking the elements of collaborative learning practices and specific aspects of students' well-being. To this aim, the study proposes an integrated conceptual model exploring the relationships between knowledge sharing, participation in academic activities, academic performance, academic burnout, and life satisfaction. The model is tested on a sample of 353 engineering students, using the Structural Equation Modelling (SEM) analysis. The results show that both knowledge sharing and participation in academic activities increase students' academic performance. Academic performance is found to decrease all dimensions of academic burnout and to increase student life satisfaction. Finally, knowledge sharing is shown to indirectly affect both student burnout and life satisfaction via academic performance. The confirmed beneficial effects of sharing and collaboration on both students' achievement and well-being underscore the need to promote and nurture these educational practices.

*Keywords:* academic performance; knowledge sharing; participation in academic activities; life satisfaction; academic burnout; SEM

**Designing and Evaluating an Immersive Extended Reality (XR) Learning Experience for Computer Science and Engineering Students** 209–220

*Hui-Tzu Chang, Jung-Hong Chuang, Chi-Min Hsieh, Hong-Yu Chang and Chuan-Chang Wang*

This study focused on an XR camp designed to integrate multiple subjects into one course, providing students with an immersive, creative, and engaging interdisciplinary learning experience. This study explored the distribution of cognitive development stages among computer science students (CSSs) and engineering students (ESs). Additionally, we compared differences in learning styles, levels of participation and contributions, and learning outcomes between the two groups and verified whether the degree of participation and contributions could predict learning outcomes. The subjects were 54 students (39 = CSSs, 15 = ESs) who participated in the XR camp course from 2020–2021. The students completed the active experiment scale in the 1st week; rated team members using a peer assessment rubric and projects using a work rubric in the 6th, 11th, and 16th weeks; completed the learning ability scales; and participated in interviews in the 18th week. Following their participation in the XR camp, 87% of the students developed high-level cognitive abilities in the XR camp. For the CSSs, course participation positively predicted cognitive development stages, work performance, and collaborative problem-solving abilities, with peer assessments positively influencing work performance. The ESs demonstrated greater interdisciplinary competence, and course participation also positively predicted work performance. These students could also apply XR knowledge and technology to other situations, confirming that the XR camp is conducive to learning for students from diverse backgrounds.

*Keywords:* extended reality technologies (XRs); XR camp curriculum design; cognitive development; learning outcomes

**Learning Undergraduate Engineering Fluid Mechanics Course assisted by Journal Articles and Research Argumentation** 221–233

*Merce Garcia-Vilchez, Miquel Torrent, Mikhail Vlasov, Lourdes Rodero-De-Lamo and Pedro Javier Gamez-Montero*

A new approach in engineering education encourages students to engage with scientific discovery by reading research articles rather than relying solely on textbooks. Although frequently overlooked in undergraduate programs, the ability to read academic papers helps students stay up to date with the rapidly evolving knowledge and skills needed by engineers in today's world. Hence, the main aim of this research-based and curriculum-oriented intervention was to determine if fourth-year undergraduate engineering students could progressively improve their academic reading skills when provided with carefully chosen articles about fluid mechanics research. The instructional intervention included warm-up readings, in- and out-of-class assignments, and best practice lectures, following an incremental approach. Test readings and test exams were correlated and subjected to quantitative analysis. Additionally, a questionnaire was administered to track student self-awareness of their own progress. During the fall semester, the cohort was randomly divided into two groups, with each group receiving a different test reading before a lecture. For the post-lecture assignments, the two texts were switched between groups. In the spring semester, all students in the new cohort received the same pre- and post-test articles. The results demonstrate that students improved in their ability to read primary literature during the intervention and developed a greater understanding of fundamental concepts. They also reacted positively to the teaching methodology and educational materials and perceived an improvement in their academic reading skills. Engineering educators may find these results useful when seeking to prepare undergraduate students more effectively. This innovative approach has the potential to train engineering students to think like engineers, and can be easily adapted to various educational settings.

*Keywords:* undergraduate research; course design; syllabus learning; research argumentation; technical courses; fluid mechanics

**Comparison of the Accreditation Status of Energy and Environment Laboratories in Brazilian, Austrian, German, and Swiss Universities** 234–244

*Diego Nascimento, Gustavo Henrique Romeu da Silva, Gustavo Rorato Tonizza De Lacerda Pereira and Mauro Hugo Mathias*

This article offers a comprehensive analysis of the implications of ISO/IEC 17025 accreditation for university laboratories operating within the energy and environmental sectors. Through bibliographical research, database development and generation of comparative indicators, it was possible to identify the current scenario, resulting in a quantitative analysis. The research had a scope comparing Brazil with Austria, Germany, and Switzerland, countries in Europe characterized by a shared cultural similarity. Brazil leads with the largest number of laboratories in energy and environment sector; however, Austria is the country with the highest proportion of university laboratories when compared to the total number of laboratories. Furthermore, it was possible to verify that this standard accredits laboratories to participate in numerous projects, boosting the number of scientific projects and research.

*Keywords:* engineering university laboratories; laboratory accreditation; ISO/IEC 17025; energy and environment sector

**Investigating Experts' Science Teachers' Perspectives on the Integration of STEM Activities into Science Instruction** 245–260

*Yousef F. Alfarraj and Roba Alzahrani*

The ambiguity surrounding the integration of engineering and technology into science and mathematics instruction poses significant challenges for educators, primarily due to varying interpretations of how to efficiently integrate these disciplines within the curriculum. This phenomenological study examines the perspectives of eight expert science educators – selected based on specific criteria – regarding the incorporation of STEM activities into their teaching practices through semi-structured interviews. Findings indicate that these educators emphasize the interdisciplinary nature of STEM education, particularly the integration of technology and engineering within science and mathematics instruction. Participants define technology as the tools and methods used to apply scientific concepts, while engineering is considered the application of these principles to design systems that address real-world challenges through authentic learning. The study emphasizes the importance of aligning STEM activities with established standards to enhance coherence and consistency, revealing benefits such as increased student engagement and the development of critical thinking skills. However, challenges – including resource limitations and insufficient content knowledge among educators – were

also recognized. Ultimately, the study advocates for transformative practices to improve the quality of STEM education, emphasizing the need for evidence-based methodologies in curriculum development, such as teacher preparation. In this context, the success of an educational system is shaped by the quality of its teachers.

*Keywords:* expert teachers' perspectives; STEM activities; phenomenology study; science education