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- Sustainable Assessment Practices for Engineering Programme Outcomes: Challenges and Recommendations in Malaysian Higher Learning Institutions** 216–230  
*Chia Pao Liew, Marlia Puteh, Shahrin Mohammad, Peck Loo Kiew and Kim Geok Tan*
- A new paradigm in the implementation of engineering programme outcomes assessment has emerged throughout Malaysia since the introduction of Outcomes-based Education (OBE) by the Engineering Accreditation Council of Malaysia in 2005. Despite the fact that OBE has been in place for over seventeen years, Malaysian Higher Learning Institutions (HLIs) continue to face challenges in effectively assessing programme outcomes. This research aimed to explore the challenges faced by academic staff when assessing programme outcomes at HLIs. The research was guided by the theory of sustainable assessment, as well as the key barriers identified by previous researchers that hinder academic staff from changing assessment practices. A qualitative methodology was employed, involving interviews with 18 participants to gain a comprehensive understanding of programme outcomes assessment in HLIs. The data was analysed using a constant comparative method, and themes were systematically examined and reported using Strauss and Corbin's coding analytical framework. The research revealed various emerging themes, including the need to change academic staff's mindset and increase their exposure to assessment, implementing effective HLI initiatives to enhance outcomes assessment, securing support from accreditation bodies to reduce assessment workload, establishing a robust outcomes-based support system, and working with dedicated and enthusiastic leaders. Based on the findings, sustainable practices for assessing engineering programme outcomes were proposed. These practices aim to address the challenges faced by HLIs and academic staff in engineering and other Science, Technology, Engineering, and Mathematics (STEM) education settings, foster the exchange of best practices, and improve the overall quality of STEM education globally.
- Keywords:* assessment practices; assessment workload; engineering programme outcomes assessment
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*Kezhi Li, Guo-Ping Liu and Wenshan Hu*
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- Keywords:* mobile learning; remote laboratory; Wechat mini program; networked control
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*Wen-Jye Shyr, Hung-Ming Liau and Chia-Wei Chang*
- This study aimed to develop e-learning materials for a blended learning course focusing on programmable logic controller (PLC) technology and assessed its effectiveness using the technology acceptance model. The course utilized the university's cloud-based learning platform as the teaching platform and incorporated specially designed targeting PLC technology. The objective was to enhance the interactivity and efficiency of the instructional activities while fostering the students' interest in programmable control technology. This study placed emphasis on helping students establish a solid foundation in programmable control technology and improving learning outcomes, thereby achieving the goals of blended instructional design. The results of questionnaire survey were analyzed using statistical methods. Structural equation modeling using SmartPLS software was used to measure the structural model. A number of conclusions were drawn based on the analysis results. First, the developed e-learning material effectively enhanced the learners' interest and learning outcomes. Second, the students generally exhibited high levels of satisfaction with the blended learning course in PLC technology, indicating widespread recognition and affirmation of the course. Third, the blended course for PLC technology demonstrated applicability in the fields of engineering and technology education.
- Keywords:* programmable logic controller (PLC); blended learning; technology acceptance model; e-learning teaching materials
- Development and Assessment of Innovative Pedagogical Approaches through a Starlink DBL Course** 255–267  
*Chih-Chao Chung, Shi-Jer Lou and Yuh-Ming Cheng*
- This study aims to develop capability indices, practical thematic course content, assessment tools, teaching materials and aids, for the Starlink DBL Program at the Science and technology university. Fuzzy Delphi Method was used as a research method. Thirteen experts and scholars in relevant fields of satellite communication technology, spectrum management, satellite applications, satellite launch, and system integration were invited to conduct significance assessments of capability indices of the Starlink DBL Program. This serves as the basis for the development of practical courses, assessment tools, and teaching materials and aids for the Starlink DBL Program. The research results show that the capability indices of the Starlink DBL Program include 5 major capability indices: the Starlink system, satellite communication technology, spectrum management, satellite network applications, and sustainable development of satellite technology, with a total of 21 detailed indicators. Most experts believed that the Starlink system capability index weighed most, followed by satellite communication technology, satellite network applications, sustainable

development of satellite technology, and spectrum management. Through experimental teaching, it was found that the student-centered 6.5-step implementation special activities of the Starlink DBL Innovation Course can help students transfer knowledge. Analysis from the questionnaire survey shows that most students expressed positive satisfaction with this Starlink DBL Innovation Course.

*Keywords:* design-based learning; technological universities; Starlink; competency indicators; education reform

### **Mixed-mode Emergency Learning: Engineering Students Experience**

268–281

*Aleksandra Sitarević, Selena D. Samardžić, Ivana M. Lončarević, Robert Lakatoš, Aleksandra Mihailović, Tanja D. Jevremov and Bojana M. Dinić*

Due to the global COVID-19 pandemic, educational institutions were compelled to transition from traditional learning to emergency remote e-learning rapidly. In light of this, the present study aims to investigate the effect of a broader range of student characteristics on attitudes towards e-learning during the pandemic in a mixed-mode learning environment. The investigated students' characteristics are gender, previous experience in e-learning, perceived level of IT skills, high school background, study program indicative of the extent of technology use, teaching method employed during the pandemic, time devoted to e-learning, the device employed for e-learning, and residence status. The newly developed Students' Attitudes Towards E-learning Scale (SAES) was administered to a sample of 1058 first-year engineering students at the University of Novi Sad. The results of factor analysis revealed three factors of the SAES: positive attitudes, negative attitudes, and institutional support for emergency e-learning. Results showed that students from different study programs showed significant differences in their perception of online learning, indicating the role of the course curriculum. Additionally, students from the gymnasium (grammar school) who attended online classes during the pandemic and had prior experience in e-learning showed more positive attitudes towards e-learning, while students who engaged in the combined teaching method in high school and spent more hours in e-learning showed more negative attitudes towards e-learning. Gender does not affect attitudes towards e-learning. Emphasising the importance of examining diverse student characteristics, this study highlights institutional support for e-learning for commuter students and those who spend more time on e-learning.

*Keywords:* emergency e-learning; mixed-mode learning; COVID-19 pandemic; engineering students

### **Empathy in Engineering Design Teams: Comparing Hybrid and Online Learners**

282–294

*Aristides P. Carrillo-Fernandez and Justin L. Hess*

Empathy is essential to engineering education, including in the domains of teamwork and design. Empathy enables engineers to consider the perspectives of their peers and can motivate teammates to act upon such understandings in supportive ways. Yet, we lack knowledge on how empathy manifests within teamwork settings or how best to promote its use in learning contexts. We aim to fill this knowledge gap by addressing two research questions: (1) "To what extent are there differences in empathy with/for team members in hybrid versus online learning modalities?" and (2) "To what extent are their correlations between empathy constructs in hybrid and online learning modalities?" We administered a survey to First-Year engineering students at a large Midwestern University in Fall 2021 which included seven constructs: Perspective-Taking, Empathic Concern, Perspective-Taking with/for teammates, Empathic Concern with/for teammates, Cognitive Collective Empathy, Affective Collective Empathy, and Behavioral Collective Empathy. First, we used non-parametric tests to compare how constructs manifested in two learning modalities (online-only and hybrid). Next, we computed Pearson's correlations to identify relationships between constructs. Our findings revealed no significant differences in how empathy manifested with/for teammates across learning modalities. There were strong correlations between the empathy constructs for both groups, but the nature of these correlations varied, with slightly larger correlations between empathic states and traits among Hybrid learners when compared to Online-only students. In our discussion, we identify lessons for promoting and assessing empathy in online and hybrid instructional modalities. This work will support engineering instructors and researchers in the assessment and promotion of empathy in engineering curriculums.

*Keywords:* empathy; teams; hybrid; online; instruction

### **A Qualitative Analysis of Student Learning After the Completion of Maker Education Programs: Influences on the Choice of Engineering Majors**

295–302

*Ai-Jou Pan and Pao-Nan Chou*

The aim of the study was to analyze the learning growth of students who previously underwent maker education training and to investigate the factors that influenced their decisions to choose engineering majors. The research focused on tracing the learning trajectory of each student from the completion of the maker program to college admission. Ten college students majoring in engineering disciplines were interviewed. A phenomenographic and qualitative research method was adopted. The research findings confirmed that computational thinking and engineering design skills, emphasized in maker education, had a positive influence on the learning performance of students in subsequent technology-related courses. Furthermore, experiences in maker learning reinforced the determination of students to choose engineering majors.

*Keywords:* maker education, qualitative study; phenomenographic research; engineering major; education reform

### **Effects of Standards-Based Testing via Multiple-Chance Testing on Cognitive and Affective Outcomes in an Engineering Course**

303–321

*Autar Kaw and Renee Clark*

Multiple-chance testing was used to conduct standards-based testing in a blended-format numerical methods course for engineering undergraduates. The process involved giving multiple chances on tests and post-class learning management system quizzes. The effectiveness of standards-based testing was evaluated through various forms of assessment, including an analysis of cognitive and affective outcomes, and compared to a blended classroom that did not use standards-based testing. Based on a two-part final exam, a concept inventory, final course grades, a classroom environment inventory, and focus groups, the results showed that standards-based testing had overall positive effects. Standards-based testing was associated with a more significant percentage of students (15% vs. 3%) earning a high final exam score, a higher proportion of A grades (36% vs. 27%), and a better classroom environment on dimensions of involvement, cohesiveness, and satisfaction. Focus group discussions revealed that students appreciated the benefits of enhanced learning, second chances, and reduced stress with standards-based testing. The study also included an analysis of the impact of standards-based testing on underrepresented minorities, Pell Grant recipients (low socioeconomic groups), and low-GPA students, as well as an examination of test-retaking behaviors. The methodology and comprehensive results of the study are presented in this paper.

*Keywords:* standards-based grading; multiple-chance tests; standards-based testing; mastery grading; traditional grading; numerical methods

### **Engineering Students Engagement Profiles while Using Low-Cost Desktop Learning Modules**

322–335

*Rachel M. Wong, Olusola Adesope, Chi Yang Chuang, Oluwasola S. Oni, Bernie VanWie, Prashanta Dutta, Kitana Kaiphanliam Felicia Adesope, Oluwafemi J. Ajeigbe and Jacqueline Gartner*

There is overwhelming research evidence showing that students often struggle with learning key engineering concepts. The Low-Cost Desktop Learning Modules (LCDLMs) are model prototypes of standard industry equipment designed for students to learn some fundamental but abstract engineering concepts in the classrooms. Previous results have shown that students who interact with LCDLMs tend to outperform those who engage in traditional lectures. However, little is known about student profiles and their

forms of engagement with this tool. Hence, the present study seeks to investigate the different student profiles that emerge from students working with the LCDLM and the demographic factors that influence student engagement with the tool. Participants ( $N = 1,288$ ) responded to an engagement survey after working with LCDLMs in engineering classrooms in several states around the United States. We then used a latent profile analysis (LPA) – an advanced statistical approach – to better understand the representation of learner engagement profiles resulting from their self-reported learning engagement beliefs as they reflect on their experience in using LCDLMs. The LPA revealed five distinct profile types – disengaged, somewhat engaged, moderately engaged, highly engaged, and fluctuating engagement. Results showed that those who are more interactive and actively engaged with the LCDLM scored higher on their questionnaire compared to those who passively engaged with the LCDLM. We conclude with a discussion of the theoretical and practical implications of our findings.

*Keywords:* low-cost desktop learning module; student engagement; hands-on learning

#### **Applying Fundamental Soundscape Concepts as a Framework for Introductory Acoustical Engineering and Music Courses** 336–343

*Felipe Otondo*

In this paper, we propose teaching strategies grounded on an interdisciplinary teaching framework based on the holistic concept of soundscape ecology. The study explores the self-perceived level of understanding engineering and music students exposed to the same foundational course communicated and expressed before and after the course. Results showed that the teaching framework chosen provides a good umbrella for teaching technical, contextual and practical topics. Students seem to grasp better courses related to theory and context than practical activities involving detailed analysis and the use of audio software. Multifaceted topics such as sustainability and interdisciplinary were also difficult to grasp for most students. Compared results for music and engineering showed that, while engineering students showed a substantially more robust background in practical activities related to audio, music students were able to easily reach similar levels of knowledge of these topics by the end of the course. As a way of reducing this gap further, future versions of the proposed course should consider ways of blending engineering and music students in the same classroom environment to foster a greater level of collaboration and interaction among students.

*Keywords:* soundscape; engineering education; interdisciplinarity; music; creativity; innovation

#### **Input Process Output (IPO) Framework for Engineering Higher Education Accreditation in Indonesia** 344–357

*Misri Gozan, Renanto, Rahmat Nurcahyo, Muhammad Asad Abdurrahman and Erni Misran*

While higher education accreditation is widely acknowledged for its benefits, it remains subject to criticism. Critics have expressed certain concerns, including the observation that accrediting bodies often exhibit a preference for an input-centric approach despite the recent trend towards emphasizing outcomes. However, establishing predetermined accreditation criteria for evaluating the performance of educational institutions is a complex and formidable undertaking. LAM Teknik, an Independent Engineering Accreditation Agency in Indonesia, is relatively new. Nevertheless, it has developed accreditation assessment criteria based on the Input-Process-Output (IPO) framework, which has been put into practice. The IPO Framework of LAM Teknik encompasses 74 scoring elements, categorized into 32 for inputs, 26 for processes, and 16 for outputs. This research aims to assess the validity of the IPO framework using data collected in 2022 from 263 undergraduate engineering programs. Data processing involved linear regression analysis, correlation analysis, and ANOVA. The results demonstrate the validity of the IPO framework developed by LAM Teknik, although the findings indicate challenges in assessing the outputs.

*Keywords:* accreditation; engineering; higher education; Indonesia

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*Juan J. Galán-Díaz, Simón F. Garrido, Ana Isabel García-Díez, Manuel Ángel Graña-López, Almudena Filgueira-Vizoso and Laura Castro-Santos*

This study explores the pedagogical approach in the first-year Applied Physics course of Engineering degrees at the University of A Coruña. Employing a comprehensive strategy, educators developed simulations to address student weaknesses identified in pre-tests. The research aims to bridge gaps by outlining objectives, elucidating methodology, and presenting tools used. Utilizing a quasi-experimental design over eight academic years, the investigation incorporates computer simulations, pre-tests, post-tests, and final exams. The primary objective is to improve engineering education through innovative methods, focusing on core principles like friction, thermodynamics, fluid rotation, and electromagnetic forces. Outcomes are showcased through various assessments, including general satisfaction surveys and specific questionnaires. Emphasizing distinctiveness, marked by inventive pedagogy, rigorous data analysis, and a sustained cohort study, the study contributes to ongoing discussions on engineering education enhancement. Ultimately, it empowers students for practical applications.

*Keywords:* active learning; engineering; easy Java simulations; computer simulations

#### **A Systematic Literature Review of Engineering Identity Research (2005–2019): Quick Reference Guide** 368–383

*Shawna Fletcher and Kristi J. Shryock*

For two decades, a growing body of research surrounding engineering identity has emerged as an indicator for interest and persistence in engineering. The purpose of this quick reference guide using a systematic literature process is to identify the scope of work regarding the development of engineering identity as a concept, specifically within undergraduate student populations in higher education (2005–2019). The original literature review focused search criteria on studies that examine underrepresented populations and their ability to navigate multiple identities within engineering enculturated environments. This work was conducted by two independent researchers and coded based on a systematic review process. Search terms for the review included: “identity” AND “engineering”, with refined search terms “women”, “women of color”, “underrepresented” and NOT “STEM” as explained in the paper. The review included 649 titles in the initial search and resulted in 43 final studies categorized into three tables. This quick reference of engineering identity literature can be utilized to reference past research, specifically in the field of engineering in higher education. The literature review was conducted on articles written prior to 2020 due to the timeline required to describe populations from a retrospective study. Researchers concluded that engineering identity research was 1) difficult to discern due to lack of uniformity across terms and factors that are easily identified and 2) contained gaps in literature, especially for studies that claimed to understand women and underrepresented populations. A summary of research is provided to provide a quick reference and comparisons of research populations, themes, and gaps.

*Keywords:* quick reference; engineering identity; systematic literature review; women in engineering; underrepresented populations; quick reference guide

#### **Validity Evidence for Parsimonious Sense of Belonging Scales for Engineering Students** 384–399

*Breanna Graven, Patricia Ralston and Thomas Tretter*

Sense of belonging has substantial evidence of being related to success in engineering and is of high interest to the engineering education field, but validation evidence for sense of belonging measurement scales is sparse. This study presents a suite of validity evidence in several categories for two parallel 4-item belonging scales; belonging in college and belonging in engineering. Data from over 3600 first-year engineering students in 8 cohorts were used to present internal consistency reliability (Cronbach alpha) evidence as well as validity evidence in 3 categories: respondent engagement validity, convergent validity, and sensitivity to societal contexts. Results are reported for whole group as well as two sets of subgroups of interest to the engineering education field: women/men and underrepresented/non-underrepresented groups. Results showed substantial evidence for both internal consistency reliability ( $\alpha > 0.82$  for all time points, all subgroups) as well as multiple strands of validity evidence for all 3 categories for

supporting interpretations both whole group as well as by subgroups. Across all results, we conclude that there is substantial evidence supporting validity of interpretations from the two parsimonious sense of belonging scales for first-year engineering students.

*Keywords:* sense of belonging; first-year engineering; validity evidence; belonging measurement; belonging scales; COVID-19

#### **Impact of Peer Learning on Students Academic Achievement and Personal Attributes**

400–409

*Bin Sha, Xiaoyu Guo and Qinfang Zhong*

Mechanics of materials courses are important and very challenging basic professional courses in civil engineering. The peer learning method is student-centered and has been widely applied in engineering education. This paper proposes many original insights into concrete ways to apply peer learning in a mechanics of materials course, which can provide guidance or inspiration for similar courses. A quasi experimental research method, final examination scores, psychological scales, and structured interviews were used to conduct quantitative and qualitative analyses on the benefits of peer learning to the undergraduate civil engineering students (N = 61). The results indicated significant differences between the experimental and control classes in terms of improved academic performance, psychological scores, and character. Specifically, the experimental class improved significantly in terms of final examination scores, deep approach, critical thinking, soft bullying, social avoidance, teamwork, etc. Thus, peer learning in a mechanics of materials course can effectively improve students' academic, character, mental health and satisfaction benefits.

*Keywords:* engineering education; curriculum benefits; team-based learning; collaborative learning; cooperative learning

#### **Application of Computational Thinking for Teaching and Learning of Undergraduate Engineering Numerical Calculus**

410–422

*José Luis Díaz, Yanko Ordoñez Ontiveros and Julián Roa González*

The integration of Computational Thinking (CT) into numerical calculus for engineering may be regarded as a new approach for introducing numerical contents promoting a logical and structured form of reasoning. This study explores the reception of this integration by analyzing the insights derived from semi-structured interviews with students. A total of 65 students participated in the classroom sessions and 24 students participated in the interviews to reflect their feedback. The interviews illuminate both the strengths of the approach, such as the tangible benefits seen in algorithmic thinking, and areas for improvement, including the need for more diverse examples and a balanced focus between CT principles and mathematical techniques. The feedbacks, received from students, reveal the importance of real-world applications and the value of iterative curriculum design. This research provides ideas towards understanding the potential of CT in traditional academic disciplines and emphasizes the significance of students' feedback in refining educational methodologies. The findings are intended to support educators when designing learning experiences in engineering education, more specifically, involving numerical calculus.

*Keywords:* computational thinking; numerical calculus; engineering education; student feedback

#### **Development and Validation of a High School Course in Refrigeration and Air Conditioning**

423–439

*Kuang-Yi Lee, Chih-Cheng Tsai, Chih-Chao Chung and Shi-Jer Lou*

This study aims to develop an innovative refrigeration and air conditioning curriculum for technical high schools using the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) instructional design model. Through instructional experiments, the appropriateness of the innovative curriculum developed with the ADDIE model is validated. The researcher initially constructs competency indicators suitable for the innovative refrigeration and air conditioning curriculum in technical high schools. Subsequently, competency-oriented modules and teaching materials are developed, encompassing “Basic Industrial Wiring Course,” “PLC Programmable Logic Controller Operation and Design Course,” and “System Integration and Comprehensive Application.” The effectiveness of the developed curriculum is assessed and validated through the evaluation of learning outcomes involving 67 second-year students from technical high schools. The results indicate that students exhibit high levels of learning effectiveness and satisfaction. Furthermore, the developed competency indicators, instructional content, and teaching materials align well with the demands of practical skills required by the industry. The proposed curriculum development model can be extended to interdisciplinary or vocational training program development, contributing to the cultivation of skilled professionals equipped with practical expertise.

*Keywords:* ADDIE; innovative courses; refrigeration and air conditioning; education reform

#### **Learning to Teach Engineering Capstone Design: An Analysis of Faculty Members' Experiences**

440–456

*Marie C. Parette, Homero Murzi, Benjamin Lutz, Maya Menon and Lisa Schibelius*

The credentials required to teach engineering at the university level vary widely around the world. In the U.S., though many universities ask for a statement of teaching philosophy as part of job applications, U.S. faculty members are rarely, if ever, required to have any form of pedagogical training or credentials, and little is known about how many, to what extent, or with what frequency engineering faculty members engage in such faculty development around teaching and pedagogy. This study draws on interview data from a larger project examining capstone teaching, asking three questions: (1) What do faculty members need to learn to teach the capstone course? (2) How do they gain this learning? and (3) How does learning vary based on engineering discipline? Analysis revealed seven learning foci and three sources of learning and examined the relationships between them. Findings suggest that beyond general strategies for course design, assessment, active learning, and student motivation, capstone faculty members need to develop teaching practices such as structuring and mentoring teams, and such learning needs to be grounded in current industry practices. Given the central role of capstone courses in preparing students for engineering practice, departments and programs may need to think more intentionally about how they prepare new faculty members for the capstone teaching role, including explicit support for professional development.

*Keywords:* capstone design, capstone pedagogy, faculty development, faculty learning, industry experience

#### **Guide for Authors**

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