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- Ahmad Ibrahim** 575 Editorial
- R. Pascual, E. Blanco, P. Viveros and F. Kristjanpoller** 576–584 Application of Microlearning Activities to Improve Engineering Students' Self-Awareness

The development of skills for life and career (SLC) is a subject that has been extensively discussed in the literature. Yet, its implementation in the engineering curricula is only at a starting point. Accelerated technological advances and major changes in the future labor market are important drivers for the exploration of how to develop SLC. Such a context offers novel challenges for engineering education. This article describes an initiative in a Mechanical Engineering program. The methodology is centered in developing students' self-awareness using time-effective microlearning activities in a course at the end of the program. Results show a significant increase in self-awareness indicators. The approach can be easily extended to explore other SLC beyond self-awareness.

**Keywords:** self-awareness; skills for life and career; micro-learning

- Renee M. Clark and Autar Kaw** 585–593 Enhancing Student Outcomes in a Blended Numerical Methods Course for Engineers: The Case for Practice and Cumulative Tests

Evidence-based testing strategies in the form of multiple cumulative midterm tests preceded by practice tests were recently introduced to a numerical methods course for engineers after the course had been taught for many years in a blended fashion. The instructor introduced these practices in fall 2019, thereby creating his so-called modified blended approach, with the objective of enhancing direct and affective assessment results in his blended classroom implementation. A statistical comparison of results from this modified approach with results from a prior semester of blended instruction was made using final exam and concept inventory scores as well as classroom environment scores based on the CUCEL. This comparison was made for students collectively and for several demographic segments of interest. Based on triangulated results from direct assessments of conceptual understanding and Bloom's taxonomy (lower levels), the modified blended approach with the testing strategies may be the preferred method for this blended classroom for students collectively as well as potentially for Pell grant recipients as a group. The classroom environment and direct assessment results from the higher levels of Bloom's taxonomy did not suggest a preferred instructional method. Support for blended instruction and practice and cumulative testing from the literature is also presented.

**Keywords:** blended classroom; numerical methods; cumulative test; practice test

- Stanislav Avsec and Magdalena Jagiełło-Kowalczyk** 594–607 Developing a Framework to Predict Factors Significant for Creative Architectural Design Performance of Freshmen and Senior Architecture Students, by Adopting and Validating the CEDA

This study aims to provide a framework to predict factors significant for creative engineering design performance of freshmen and senior architecture students. Since different environments demand utilisation of a rather interdisciplinary approach of design-cognition types of teaching and learning, an advanced model of creative engineering design process has been proposed to measure multifaceted effects of the architecture study programme. For the study, 108 freshmen and 98 senior architecture students were surveyed for attitudes towards engineering, proactivity, situational interest, perception of learning, and satisfaction with design work environment and tested for creative engineering design on fluency, flexibility, originality and usefulness of designs or solutions generated. Two models were developed based on social cognition supported by self-determination theory using predictive modelling. Results demonstrate that for freshmen creative design work is not well explained by the social-cognitive theory model, while for their senior counterparts the same is strongly explained. Student proactivity was a crucial predictor in perception of control over learning solution-based creative design work, especially in senior students. As the strongest negative predictor, tediousness toward engineering was identified in social-cognitive learning, pointing to the importance of engineering knowledge, beliefs, opinions, emotions, and responses towards wider definition of technology and engineering. Such students more likely do not utilise potential of technology and engineering to work on problem- and solution-driven design tasks to develop creativity. The findings are of particular interest for architecture education curriculum designers, design course conductors and different organisations to provide sustainable, creative and market-competitive design solutions.

**Keywords:** design process; architectural education; engineering creativity; social-cognitive framework; predictive modelling

- Ahmed Osman, Eric Cuellar, Shane A. Brown and Benjamin D. Lutz** 608–623 Exploring Engineering Faculty Beliefs and Practices on Student Evaluation and Pedagogy

Evaluation of teaching is an integral component of engineering education that is designed to improve student learning and faculty practices. But the data and methods used to conduct evaluation can affect the way faculty make pedagogical choices. The purpose of this research is to explore the ways in which institutional evaluation approaches influence the perceptions and actions of engineering faculty and in particular, the way faculty use these data to make changes or improvements to their teaching. We ask the following question: How do engineering faculty beliefs and practices about pedagogy influence their perceptions of institutional evaluation methods? We conducted interviews with 29 engineering faculty at a high-research activity university in the Pacific Northwest. Using thematic analysis, we examined beliefs and practices related to pedagogy and evaluation. Findings are presented

in terms of four major themes: (1) pedagogy beliefs, (2) pedagogy practices, (3) evaluation beliefs, and (4) evaluation practices. Faculty beliefs about teaching inform a range of responses related to their concrete practices in the classroom. At the same time, however, faculty were unsure as to whether institutional evaluation practices offered meaningful insight regarding their effectiveness as educators. Findings suggest that while faculty recognize the importance and value of different evaluation methods and recognize the role of evaluation in improving their teaching, they also identify a range of challenges associated with existing measures common to most universities. Given the range of purposes that evaluation data is designed to serve, and the fact that the same data might be used to offer both formative and summative feedback, the authors recommend aligning evaluation practices and instruments with evidence-based instructional strategies which are responsive to the contexts in which they are deployed.

**Keywords:** qualitative research; student evaluation of teaching; engineering pedagogy; interviews

**Kitana M. Kaiphanliam, Arshan Nazempour, Paul B. Golter Bernard J. Van Wie and Olusola O. Adesope** 624–639 Efficiently Assessing Hands-On Learning in Fluid Mechanics at Varied Bloom's Taxonomy Levels

The present study examines the effects of hands-on low-cost desktop learning modules (LCDLMs) in a fluid mechanics class consisting of 27 junior-level chemical engineering students. The LCDLM is a miniaturized venturi meter with standpipes that aid in visualizing pressure trends through the device. Pre- and post-assessment questions were administered to evaluate learning gains across different levels of Bloom's Taxonomy: remember, understand, assess, analyze, and evaluate. Findings show that the LCDLMs produce statistically significant pre/post effects at higher Bloom's level questions compared to the lecture group. Additionally, questions that incorporate the LCDLM design and associated experiments show higher significance in comprehension gain in comparison to questions that are not as closely related. These findings suggest that although the LCDLMs are effective in enhancing student performance at higher Bloom's levels, the design of the assessment questions and how they relate to the LCDLM is an important factor in properly assessing the effects of our novel teaching device on student performance in the fluid mechanics course. Theoretical and practical considerations for these findings and what they mean for future assessments of the LCDLMs are discussed in this manuscript.

**Keywords:** hands-on learning; active learning; ICAP hypothesis; classroom implementation; fluid mechanics

**Piotr Dębiec** 640–649 Digital Systems and Dedicated Screencasts – A Case Study in Engaging First Year Engineering Students

This paper presents a case study of teaching introductory digital systems to first year students by augmenting in-class active learning with a set of short educational videos to be studied out of class. The main objective of the experiment was to reduce the course dropout rate and improve exam performance. Twenty eight course-dedicated screencasts were recorded and uploaded on YouTube. Topics of a number of videos were selected by students. The video usage statistics and student survey revealed that the videos were watched at high intensities in a variety of styles. The reduction of dropout rate and improvement of exam grades, compared to active learning alone, confirmed a very good synergetic effect of these strategies. Yet another positive "paradoxical" outcome was an increase in student attendance rate at face-to-face lectures. The paper presents the rationale of the design decisions and discusses the results of the three-year experiment.

**Keywords:** active learning; screencasts; first year; instructional design; digital systems

**Eric Burkholder and Carl Wieman** 650–662 Impact of Decision-Making in Capstone Design Courses on Students' Ability to Solve Authentic Problems

Previous work in problem-solving has been limited by lack of a framework to describe how experts solve authentic problems, and a lack of assessments to measure authentic problem-solving. We have developed an assessment of expert problem-solving in the context of chemical process design to measure how well undergraduate engineering students are learning to solve authentic problems. We measured changes in students' problem-solving over the course of two different capstone design courses to see (1) how much students learned and (2) whether problem-solving outcomes varied between the two courses. We find that students are learning some problem-solving in capstone design courses, but not as much as one might hope: scores on most metrics of expertise range from 30–70%. Variations in what students learned between the two courses can be explained by what decisions students were given an opportunity to practice making during the course. These results suggest that undergraduate students need more deliberate practice making the decisions that expert engineers do as they solve authentic problems.

**Keywords:** problem-solving; decision-making; capstone design

**Lynal Albert** 663–671 Educational Interventions for Civil Engineering Students: Thematic Review and Future Opportunities

Civil engineers play a pivotal role in addressing key societal and global issues. Accordingly, civil engineering educators are tasked with equipping their students with multi-disciplinary skill-sets that empower them to evaluate and solve critical challenges – which include sustainability, safety, transportation, housing, and other infrastructure needs. To accomplish these educational goals, much research has focused on designing, delivering, and testing educational interventions that immerse civil engineering students into relevant learning experiences. The knowledge gained from these research efforts is largely dispersed and fragmented – which is currently a barrier to the development of a robust and proven civil engineering curriculum. The current research summarizes some of the educational interventions that have been developed and tested with students pursuing a civil engineering career to answer questions such as: what problem areas does the developed interventions seek to tackle, what are the characteristics and elements of the interventions, what problem areas have the educational interventions not addressed? The primary objectives of the article were accomplished through a comprehensive review of literature across areas including construction engineering, environmental engineering, structural engineering, transportation engineering, geotechnical engineering, and others. Apart from examining the gaps in the broader literature, the article will serve as a concise resource that can help engineering educators and university administrators develop a robust learning experience for their civil engineering students.

**Keywords:** STEM education; engineering education; interventions in engineering education

**Douglas B. Clark, Christopher Ostrowdun, Stefan Rothschuh and Senay Purzer** 672–689 Assessing Students' Design Processes and Design Outcomes

Classroom assessments can affect what is valued, taught, and learned by teachers and students. It is therefore of great importance to review the approaches proposed for assessing student design (processes and outcomes) given the increasing focus on design in STEM curricula. We reviewed 17 prominent journals that address STEM and design education. Inclusion criteria and search terms were identified through a systematized process. Database searches resulted in 2101 raw hits. Articles that straddled the borders of the inclusion criteria were first reviewed at the abstract level by the researchers. We then reviewed the main text of each article and evaluated whether the assessment instruments therein were described in sufficient detail to meet the criteria. The literature search resulted in a sample of 27 articles. Most of the articles (23 of 27) were in engineering education journals and four were in a design journal. We performed a content analysis of the final 27 articles with a goal of identifying key components of assessment in terms of design foci, student age, evaluator type, project type, and granularity of assessment. The majority (20) included a focus on performance of the design, and a substantial number included a focus on communication (15) and scoping (11). While less prevalent, divergent thinking (9), creativity (9), convergent thinking (8), and collaboration (8) were also broadly represented. Ethical considerations were not strongly represented in the reviewed assessments, although there were notable exceptions.

**Keywords:** design, assessment; design processes; design outcomes; review

**Kadir Kozan, Muhsin Menekse and** 690–700 Exploring the Role of STEM Content, Professional Skills, and Support

This study explored the prediction of undergraduate engineering students' mid-college academic performance by their perceived needs as they relate to science, technology, engineering and mathematics content, professional skills, and support service. To this end, hierarchical multiple regression analyses were employed controlling for college admission test performance, residency, gender, and underrepresented minority status ( $N = 2834$ ). Results revealed that college admission test performance was the strongest predictor, and perceived needs contribute to the prediction of mid-college academic success statistically significantly above and beyond the controlled predictors with a relatively small effect size. Furthermore, perceived needs played a significant role in the medium-size prediction of mid-college academic success in tandem with other predictors. Accordingly, it is reasonable to suggest engineering departments and higher education institutions pay attention to their incoming engineering students' perceived needs and address those needs before they may negatively impact their academic success and potentially retention in their major.

**Keywords:** academic success; engineering education; mid-college; student needs

**Amanda D. Moreno-Hernandez and  
Joi-Lynn Mondisa**

701–711 Differences in the Self-Perceptions of Resilience, Grit, and Persistence among First-Year Engineering Undergraduates

There is a significant demand for science, technology, engineering, and mathematics (STEM) graduates to meet impending workforce needs. However, some research studies seem to indicate that academic and personal challenges deter students from persisting toward degree completion. Resilience and grit are often seen as critical attributes to counter these challenges. By understanding the roles of resilience, grit, and persistence in engineering undergraduates' experiences, institutions can develop, implement, and improve mechanisms that assist in student retention. This work examines the potential differences in the self-perceptions of resilience, grit, and persistence among first-year engineering undergraduates. For this study, we developed an online survey compiled from existing validated scales and administered the survey to first-year engineering undergraduates at a large Midwestern university. An analysis of variance (ANOVA) was performed on a sample of 167 students to determine differences between groups based on sex, grade point average, race, and citizenship. Results indicate that students' resilience and grit may extend beyond their academic experiences. There were also differences among participants' self-perceptions across race and sex when evaluating self-assessment of resilience and among citizenship status when evaluating grit. However, there was no statistical significance found when evaluating persistence contrary to findings from other studies. Additional qualitative research (e.g., interviews) is recommended to understand additional underlying factors of these findings. This study warrants the need for institutions to collectively address the role of resilience, grit, and persistence in the experiences of first-year engineering undergraduates. As a result, this work may assist in identifying strategies that help address the needs of engineering students and support their matriculation into the STEM workforce.

**Keywords:** engineering undergraduates; persistence; resilience; grit; underrepresented minorities; minoritized populations

**Wei Zhan, Byul Hur, Yonghui Wang,  
Suxia Cui and Bugrahan Yalvac**

712–720 Creating Maker Culture in an Engineering Technology Program

Many engineering technology students struggle with theoretical concepts in courses like Control Systems. Maker Culture can provide an attractive option to enhance student learning. In order to help students, Maker Culture was introduced in the Control Systems course in the Electronic Systems Engineering Technology program at Texas A&M University. Laboratories were converted to a makerspace kind of environment. Students proposed their project ideas and worked on their project during laboratory sessions. A Mini-Maker Faire was held at the end of the semester, replacing the traditional project demonstrations and presentations. The most important lesson learned is that a successful implementation requires delicate planning. This paper presents the design of lectures, laboratories, and the course projects to cultivate Maker Culture in an engineering technology program. Evaluation of the effort and analysis of data are discussed.

**Keywords:** Maker Culture; Maker Faire; Engineering Technology; Control Systems

**Vasu Kumar, Bimal Nepal and  
Michael D. Johnson**

721–732 Assessing Skills Gap in High Value Manufacturing: An Oil and Gas Industry Continuing Education Case Study

Prior research reveals that there is a gap in the skill set of new hires (especially in fresh college graduates) with respect to what is needed to perform advanced manufacturing jobs in industry. Several methods are being employed by both industry and academia to narrow the gap. Academic institutions are designing industry oriented and project-based curricula while industry is partnering with community colleges and universities in supporting capstone projects and developing short courses to meet their needs. This paper investigates the skills gap in high value manufacturing, especially in the energy industry. The research utilizes an energy industry focused continuing education case delivered to 53 participants as a tool to understand the current skill level of the participants and their self-beliefs about the preparedness of the new hires, particularly those who join fresh from higher education. A structured survey methodology is used to assess the program outcomes and investigate the skills gap in the current workforce. The paper also investigates if there are any significant differences in the perceived skills gaps in the current workforce and new hires based on gender, ethnicity, and education of the participants. The case study findings show that current and newly hired industry workforce lacked the needed skills in some key areas of high value manufacturing. The perception of the skills gap in new hires varies by age, gender, and education level of the participants. On the other hand, the case study analysis does not find any statistically significant difference in the skills of current workforce based on the participants' demographic data or the type of industry they work for. The study also finds a significant difference in perceived preparedness level between the type of HVM topics among all groups (participants themselves and current workforce and new hires in their industry).

**Keywords:** employee skill gap; high value manufacturing; self-assessment; continuing education

**Justin L. Hess, Nicholas D. Fila,  
Eunhye Kim and Senay Purzer**

733–743 Measuring Empathy for Users in Engineering Design

This study describes the design and testing of an instrument that measures engineering student tendencies to empathize with users in the context of engineering design. The instrument design seeks to measure three empathy types: Affective Empathy, Imagine-Self Perspective-Taking, and Imagine-Other Perspective Taking. Moreover, the survey includes three sections wherein students respond to how they utilized empathy distinctly in three phases of engineering design: (1) Needfinding, (2) Concept Generation, and (3) Evaluation. We performed confirmatory factor analyses on two distinct construct configurations. First, we created measurement models that sought to measure empathy types without accounting for design phase. Second, we created measurement models that accounted for how these empathy types might manifest distinctly by design phase. We were able to achieve robust measurement models in both configurations, but the set that accounted for design phase enabled the retention of all survey items, thus suggesting the importance of accounting for how these empathy types manifest distinctly across design. However, at this stage of survey development, measuring empathy types by design phases still poses internal consistency concerns due to a limited number of items. Future work involves expanding the set of items for each empathy type within each design phase, distinguishing between affective empathy types, and building on qualitative data to ensure the instrument covers all aspects of students' design experiences wherein empathy manifests.

**Keywords:** empathy; design; instrument design; validation

**Giacomo Barbieri, Kelly Garces, Sepideh Abolghasem, Santiago Martínez, Manuela Fernández Pinto, German Andrade, Felipe Castro and Fernando Jimenez** 744–760 An Engineering Multidisciplinary Undergraduate Specialty with Emphasis in Society 5.0

A substantial reform of undergraduate engineering education is necessary due to the increasingly complex and technologically driven workplace, political, and social arenas of the 21st century. Apart from technical skills, engineering students should acquire a broader set of essential skills through different student-centred learning approaches where engineering disciplines should be integrated with ethics and sustainability approaches in a more multidisciplinary environment. In response to these challenges, in this article we present a proposal for an undergraduate specialty in Society 5.0 for the School of Engineering at the University of Los Andes (Bogotá, Colombia). The specialty introduces students to the concept of Society 5.0 and provides essential and technical skills concerning selected technologies of the digital transformation age. The acquired knowledge is further applied to build prototypes for facing societal problems, and the proposed solutions are validated with respect to technical, ethical, and sustainability requirements. Given the deep social inequalities present in Colombia, and the increased ecological footprint in the country, we expect that the specialty increases the interest in the topic of Society 5.0, applies it in practice, and therefore contributes to the sustainable development of the country.

**Keywords:** engineering education; Society 5.0; ethics; sustainability; multidisciplinary education

**Muhammad Saleem, Asif uz zaman, Mohammed Aman and Faisal Albatati** 761–768 A Proposed Roadmap of Transition to the New EAC-ABET Student Outcomes

Criterion 3 – Student Outcomes (SOs), defined by Engineering Accreditation Commission (EAC) of the Accreditation Board for Engineering and Technology (ABET), is one of the General Criteria for baccalaureate level engineering programs seeking accreditation. SOs were first drafted nearly three decades ago with an intent to shift to outcome-based education. Since then, except for some minor changes in Criterion 3 (C3), the set of SOs remained unchanged. It was only in fall 2017 that EAC of ABET revised C3 and other sections with approval from the Engineering Area Delegation (EAD). The major feature of this amendment is the use of new language for C3 modifications and definitions. The revision has resulted in seven new SOs (1–7) replacing the previous eleven SOs (a–k). These changes have obligated engineering programs, scheduled for a General Review from the 2019–20 cycle onwards, to manifest and practice a structured transition to the new SOs assuring as much implementation as practical. The authors, through this paper, have attempted to propose a transitioning model from the old SOs (a–k) to the new ones (1–7). The proposed Key Performance Assessee (KPA) model could be a promising tool in addressing the latest recommendations of the EAC's changes to criteria 3 and definitions while being easy to adopt. This model is structured on the performance indicators based on the platform of C3 with new definitions. With the help of KPA model, the seemingly difficult process of transition is expected to become simple and easy.

**Keywords:** student outcomes; transition; performance indicators; criterion 3

**Martin Jaeger, Aigul Nagimova and Desmond Adair** 769–784 Perspectives on Engineering Competencies and Competency Development Approaches – Early-Career Engineers *versus* Managers of Engineers

It has been claimed that a better understanding of the needs of engineering practice is necessary in order to improve students' preparedness for engineering work. The fourfold purpose of this study is to compare perspectives on engineering competencies between early-career engineers and managers of engineers in leadership positions regarding, importance, satisfaction, contribution of Project Based Learning (PBL) and contribution of traditional learning. Based on a set of sixteen engineering competencies, questionnaire based interviews are carried out resulting in usable responses from 92 managers of engineers and 67 early-career engineers. Fuzzy TOPSIS analysis is applied. Results show that engineering educators should give more importance to competencies related to professional and personal attributes. Furthermore, students should be exposed more often to a larger variety of real life problems, and PBL should be the primary learning approach for 12 of the 16 analysed competencies.

**Keywords:** engineering competency; competency development; early-career engineer; manager; fuzzy TOPSIS

**Teodora Lolic, Darko Stefanovic, Rogerio Dionisio, Ugljesa Marjanovic and Sara Havzi** 785–796 Assessing Engineering Students' Acceptance of an E-Learning System: A Longitudinal Study

Although previous research on the e-learning system acceptance has been conducted using UTAUT, no study followed the longitudinal approach. Accordingly, this research examines the engineering students' (N = 291) e-learning system acceptance by three years of study. The structural equation modelling analysis confirmed UTAUT relationships in each year. Effort expectancy and social influence resulted as significant predictors of behavioural intention in all three years. In contrast, performance expectancy influence got lower in later usage. Altogether, our longitudinal study presented that the UTAUT model has weakened over time. Therefore, we propose extending the UTAUT model in future research to better understand user satisfaction and positively contribute to system acceptance. Our research findings can be used for university leaders to investigate and evaluate any implemented information system acceptance through the years.

**Keywords:** e-learning; engineering students; UTAUT; SEM; longitudinal study

**Rebecca Brent, Michael Prince and Richard Felder** 797–813 Promoting and Managing Student-Student Interactions in Online STEM Classes

The power of collaborative activities to improve students' learning, curricular retention, self-efficacy, and attitudes toward their instruction in face-to-face college classes is well supported by research. Whether the instruction qualifies as active learning, collaborative or cooperative learning, or an inductive approach such as inquiry-based, project-based, or problem-based learning, as long as the collaborations follow research-validated guidelines, the students on average outperform students taught entirely with lectures and individual assignments. A smaller but still substantial body of research shows similar benefits for online collaborative activities, but questions remain regarding the effectiveness of such activities and how best to implement them. This paper outlines synchronous and asynchronous online collaborative activities suitable for STEM courses, surveys research on the impacts of such activities on students' learning and attitudes, suggests effective implementation strategies, and offers recommendations for additional research.

**Keywords:** active student engagement; cooperative learning; discussion boards; online

**Filippo Sanfilippo and Kolbjørn Austreng** 814–829 Sustainable Approach to Teaching Embedded Systems with Hands-On Project-Based Visible Learning

Although purchasing state-of-the-art teaching equipment may be financially demanding, substantial efforts are being made at the Norwegian University of Science and Technology (NTNU) in Trondheim to provide students with an enhanced hands-on embedded system design experience in a sustainable manner. In particular, an approach that consists of adopting low-cost commercial off-the-shelf (COTS) components and tools for learning purposes is proposed in this work. This strategy effectively combines both industry standard highly-reliable automation controllers, such as *Programmable Logic Controller* (PLC) technology, as well as novel microcontrollers (i.e., the micro:bit microcontroller based on the nRF51822 system-on-chip (SoC)) explicitly designed for use in embedded systems education. This contributes towards a hands-on sustainable learning experience based on the applicability of *Visible Learning* (VL). The objective of this paper is to propose a novel organisation of the embedded systems

module for the engineering cybernetics education curriculum. The intended outcome is to promote a novel teaching approach. This is achieved by engaging students in both a series of organised theoretical lectures as well as practical and highly involving laboratory group projects. Surface learning sections and deep learning sections are thoroughly alternated to stimulate understanding, making relations, and extending the students' knowledge. The course organisation and main topics, as well as result analysis of student surveys are discussed. The survey results and feedback from the reference group indicate that the course organisation and topics are effective and helpful for students.

**Keywords:** embedded systems, education, programming, micro:bit

**Aharon Gero and Yinnon Stav**

830–840 Summative Assessment Based on Two-Tier Multiple-Choice Questions:  
Item Discrimination and Engineering Students' and Teachers' Attitudes

Summative assessment is carried out at the end of the teaching process, and should be objective, reliable and valid. The standard multiple-choice test is a common summative assessment tool in engineering education. However, one of the main arguments against this test is that it examines only lower-order thinking skills. A possible solution is the use of two-tier multiple-choice questions. The research described in the paper characterized summative assessment, based on two-tier multiple-choice questions, in a course on electric circuits. The study compared the discrimination level of two-tier multiple-choice questions to that of their one-tier counterparts, and explored students' and teachers' attitudes toward incorporating the former into the final examination. The study, which used quantitative and qualitative instruments, involved 575 sophomore electrical engineering students at the Technion – Israel Institute of Technology. The findings indicate that the discrimination level of two-tier multiple-choice questions is significantly higher than that of their one-tier counterparts. Both students and faculty believe that two-tier multiple-choice questions can examine higher-order thinking skills and that their discrimination level should be higher than that of one-tier questions. They further agree that two-tier multiple-choice questions are not applicable to every subject.

**Keywords:** assessment; two-tier multiple-choice questions; item discrimination; attitudes; electrical engineering

**Lizeth Del Carmen Gutierrez Púa, Loraine**

841–852 The Impact of the Conceptual Mind Facts Methodology on the Academic  
Performance of Engineering Students

**Stephany Bruges Martínez, Ana María**

**Fonseca Reyes and Virginia Nathaly Paredes**

**Méndez**

This study explored the impact of an innovative learning methodology, Conceptual Mind Facts (CMFs), on the academic performance of mechanical engineering and industrial engineering students at the Universidad del Norte, Barranquilla, Colombia. This approach was applied in the theoretical component of the Materials Science module undertaken by these students. The reason for selecting this subject was due to the high percentage of students (greater than 80%) failing this course in recent years. Failure was particularly likely among students with a cumulative grade point average (GPA) less than 3.24 points (so-called type III students). The sample comprised 992 students (414 in the control group and 578 in the experimental group) during three study periods. A quantitative quasi-experimental research design was used, including three measurements composed of the scores achieved by students on the three assessments of the Materials Science module. Statistical analysis showed that CMFs helped students develop the skills needed to improve their performance in the theoretical component of the module, which lead to a decrease in the number of students failing the course. Importantly, CMFs were also revealed to increase the number of type III students passing the module. Therefore, it was evident that the use of this pedagogical tool had a positive impact on the academic performance of students.

**Keywords:** Conceptual Mind Facts; *Mentefacto Conceptual*; academic performance; learning strategy; instruments of knowledge