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<b>Ahmad Ibrahim</b>	299	Editorial
<b>Isam Alyaseri</b>	300–310	Problem-Based Service Learning to Improve Solid Waste Management in Iraq

Improper solid waste management (SWM) is severe in Al-Muthanna Province in southern Iraq. One reason believed to lead to this situation is the lack of SWM engineering courses. Al-Muthanna University, in partnership with Tennessee Tech University, worked to (1) establishing an environmental problem based service learning (EPBSL) course in the topic of SWM at the Department of Civil Engineering; (2) conducting an individual assignment to assess wastes characteristics by designing data collection methodologies, analyzing impacts, and making decisions; (3) using student graduation project to test solid waste properties at the dump and the institutional sites and to evaluate the environmental damages related to open burning of wastes. A quantitative indicator showed adequate achievement to the project objectives related to students learning, community service, and instructor performance. Students had developed a set of recommendations, used life cycle assessment for environmental evaluation, and worked closely with the municipality to propose solutions. The study introduced a model for establishing and assessing an EPBSL program. It also showed that EPBSL needs to be designed carefully in developing countries and may achieve high success.

**Keywords:** solid waste management; problem-based service learning; learning assessment

<b>Meg Handley, Jeff Plumlee, Brett Tallman, Brian Novoselich, Seth Sullivan, Tim Kennedy, Lori Houghtalen and May-Ling Tan</b>	311–324	Engineering Leadership Across Disciplines: A Systematic Literature Review
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Accrediting bodies, the National Academy of Engineering, and industry representatives have indicated that future engineers must be able to both understand and apply leadership in solving engineering problems. In response, the concept of engineering leadership has grown dramatically over the past decade. This paper presents a systematic literature review of the field of engineering leadership, describing how engineering leadership is being understood, applied in industry, and assessed across a variety of engineering disciplines. The literature suggests that some fields, such as industrial engineering and civil engineering, have more quickly pushed into education research in engineering leadership. Definitions of engineering leadership have not converged to a consensus, but common attributes, skills and competencies have emerged across disciplines. The literature highlighted a variety of different courses, programs, and training that worked to develop leadership skills within engineers. However, across fields, the literature suggests a deficiency in validating these proposed solutions through objective assessment.

**Keywords:** engineering leadership; interpersonal; competency models; engineering education; early-career engineers

<b>Jimoh Bakare, Ariyo Samson Oluwatimilehin, Samson Ikenna Nwaodo, Obe Pauline Ijeoma, Amenger Maashin and Akpokiniowo Duke Ejaita</b>	325–340	Assessing the Differential Effectiveness of Computer Tutorial and Simulation Techniques on Students' Achievement and Self Efficacy Belief in Vocational Electronic Technology Courses
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This study investigated the differential effectiveness of computer tutorial and simulation techniques on students' achievement, interest, self efficacy belief and retention of learning in vocational electronic technology courses. The participants were 110 third year students from two public universities in Enugu State, Nigeria. The instruments used for data collection were vocational electronic technology psychomotor test (VETPT), vocational electronic technology interest inventory (VETII) and vocational electronic technology self efficacy instrument (VETSEI). These instruments were validated by experts and the intrinsic validity was carried out on VETII and VETSEI using Rulon's formula. The Kuder–Richardson Formula 20 (KR-20) was used to determine the reliability index of VETPAT. The internal consistency of the VETII and VETSEI was also determined using Cronbach alpha reliability method. The test scores generated from the pre-test and post-test using VETPT, VETII and VETSET were analyzed using Mean and Analysis of Covariance (ANCOVA) to answer research questions and for testing the null hypotheses. The findings revealed higher mean achievement and interest among students taught vocational electronic technology with simulation technique compared with those taught in computer tutorial environment. The main effect of computer tutorial on self-efficacy and academic retention of students in vocational electronic technology was higher than the effect of simulation technique.

**Keywords:** computer tutorial; simulation technique; self-efficacy belief; retention; vocational electronic technology

<b>Ali Rizwan, Hemaaid Alsulami, Afif Shahzad, Nabilah Elnahas, Shahad Almalki, Rahaf Alshehri, Malak Alamoudi and Hind Alshoaibi</b>	341–350	Perception Gap of Employability Skills between Employers' and Female Engineering Graduates in Saudi Arabia
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The objective of the work is to explore possible perception gap between female engineering graduates and industrial employers about the employability skills. A five-point Likert type scale questionnaire was administered to 355 senior engineering students

from six universities and 81 industrial employers in Saudi Arabia. After checking the reliability of data, gap analysis, independent sample t-tests and paired t-tests were used to analyze the data. Results indicated a significant gap between students' perception and employers' expectation. Employers were found to give more importance to basic skills of communication, interpersonal and creativity, while students considered their technical capabilities more important in getting them jobs. Further analysis revealed that students' skill level is less than their perceived importance about these skills. This study gives an insight for the betterment of engineering programs.

**Keywords:** female engineering graduates; employability skills; employers; educational leadership; higher education

**Hui Liu and Yu-Qi Lin**

351–361 Factors Influencing Pharmaceutical Engineering Undergraduates to Pursue Graduate Studies

This study investigates factors that influence pharmaceutical engineering undergraduates whether to pursue graduate studies. Data were collected through an online survey sent to 400 students. Logistics regression analysis indicates that three variables are significant predictors of undergraduates' intention to pursue graduate studies. They include: year in school (freshman, sophomore, junior, or senior), place of birth (city, town, or country), and academic grades. Furthermore, to advance the career and to increase the salary are considered to be the most important incentives to pursue a graduate degree. Tuition fees are ranked lowest priority to influence their choices, but it varies significantly among students from different levels of family income. It was also found that male undergraduates prefer to perform research work, whereas female undergraduates are more inclined to serve at public institutions and government agencies. The implications of the findings for recruitment and retention of pharmaceutical engineering undergraduates are delineated in the study.

**Keywords:** graduate programs; pharmaceutical engineering; higher education; logistic regression; gender

**Wen-Lan Hsieh, Adriana Signorini, Po-Ya Abel Chuang and Wei-Fan Chen**

362–375 Investigating Students' Experiences and Perceptions of a Flipped and Adaptive Online Engineering Thermodynamics Class

The trend of incorporating flipped learning to create active and effective learning environments has become increasingly popular in higher education in recent years. Existing research in Science Technology Engineering and Mathematics (STEM) suggests that students have a positive attitude towards flipped learning. This positive attitude strongly correlates to the perceptions of enhanced motivation, effective learning, and engagement. However, most of the studies on flipped learning in higher education only yield quantitative results. Students' perceptions of their experiences of online learning, in particular of their motivation in flexible and effective learning environments are rarely investigated qualitatively to provide in-depth reasoning. Recent online pedagogy has integrated adaptive learning tools to meet individual learning needs. This study focused on both flipped and adaptive learning strategies implemented in an online thermodynamics class. The flipped classroom freed up lecture time for interactive and effective online learning activities. This study aimed to interview, analyze, and explore underlying themes of college students' perceptions and experiences in an online Thermodynamics class using flipped and adaptive learning. A total of 14 out of 54 students volunteered for a semi-structured interview. Students from the Students Assessing Teaching and Learning program were trained to conduct the individual interviews and transcribe the recording for analysis. Three researchers analyzed the data using thematic analysis. The results indicate that flipped learning enhances the students' learning experience and perceptions of learning effectiveness, ownership, and motivation. Nevertheless, applying adaptive learning with pre-designed learning algorithms can cause student frustration. Through examination of the three psychological needs of the self-determination theory, adaptive learning can be perceived as a positive experience if a student's extrinsic motives align well with his needs and values. The qualitative findings of this study not only demonstrate the effectiveness of modern learning technologies in an engineering course, but also provide a foundation for future pedagogical design.

**Keywords:** engineering education; perception; learning experience; motivation; flipped learning; adaptive learning; online learning; self-determination theory (SDT); thematic analysis

**Ammar Y. Alqahtani**

376–387 Employment Expectations of New Engineering Graduates and the Demands of Labor Market: A Case Study

The unemployment of fresh engineering graduates has been an issue in this modern world where the outcome from the educational institutions does not meet most of the expectations of the employers. The Kingdom of Saudi Arabia is planning to decrease the unemployment rate from 12.5% to 7% by 2030, which is very important to create alignment between the job market and the education system to fill this gap. The objective of this paper is to discover the type of skills and abilities needed in the labor market to enhance the competencies of fresh graduates through conducting three different surveys for students, employers, and faculty members around KSA. Results show that employers believe that fresh graduates barely can exceed 75% of job requirements (Knowledge, Skills, and Experience). Also, the labor market demands proficiency of the English language while the level of students do not meet the expectation. Moreover, gender is the main factor causing this gap as female engineers have way less possibility to be hired in the Saudi market compared to male engineers. The study suggests that more collaboration is needed between governmental institutions to fill this gap.

**Keywords:** engineering graduates; employability skills; labor market; employers; perception; Saudi Arabia

**Yaxin Huang, Jiabin Zhu and Bing Chen**

388–396 Investigating the Impact of Engagement in Prior International Learning Experiences on Engineering Students' Learning Outcomes

International learning experiences have been increasingly adopted by engineering colleges and universities to prepare future engineers with global competencies. However, the effectiveness of such learning experiences remains to be further studied and validated. This study reported quantitative analyses of survey responses from 454 engineering students who participated in thirteen international summer programs at a leading Chinese research university. Specifically, the study examines the impact of students' prior international experiences on their current learning outcomes through international summer programs. Using a prior validated instrument-Engineering Students' Learning Outcomes survey (ESLO), we explored different impacts that were associated with various forms of prior international learning experiences. Prior engagement in international summer programs, international tourism, and courses with a global focus were proved to contribute to engineering students' development in skills or attitudes. Such an exploration of impact of various international learning experiences can help multiple stakeholders in designing and choosing suitable international experiences for engineering students.

**Keywords:** international experiences; engineering students; learning outcome

**Zoran Stojadinović, Marija Božić and Ana Nadaždi**

397–408 Development and Implementation of Evaluation Framework for Quality Enhancement of Outcome-Based Curriculum

Evaluation to improve teaching and learning is essential for achieving the objectives of higher education programs. While structural and organisational aspects of teaching are frequently assessed, programme evaluation tools are rarely matched to specific learning objectives and competence levels that students are expected to achieve. Driven by the shortcomings of previous unstructured surveys on the quality of teaching at our Faculty, we created a curriculum improvement framework based on the evaluation tool that compares the level of competence that students perceive they achieved in each of the courses, and the level of competence that professors attribute to their courses by quantifying the learning outcomes using Bloom's taxonomy. In our two year study, which included seven teachers who teach 16 courses and 38 and 24 students in two consecutive years, this framework provided the educators with the indicators for quality enhancement based on the difference between students' and teachers' evaluations. Based on indicator values, the teacher implemented improvements on two pilot courses. In the second round of surveys, we were able to

measure the success of improvements. Our findings indicate that the proposed framework and evaluation tool are simple to implement and can be used as indicators and starting points for improving the quality of teaching. In this way, we provide a practical framework for others wishing to enhance their teaching and their students' learning.

**Keywords:** outcome-based curriculum; evaluation; curriculum improvement; student-teacher alignment; Bloom's taxonomy; civil engineering

**Krištof Debeljak, Slavko Kocijancic and Boris Aberšek** 409–419 Comparison of the Efficiency of Textual and Iconic Programming Environments for Teaching Programmable Logic Controllers

The rapid development of modern technologies affects all segments of society. Programmable Logic Controllers (PLCs) are key elements of autonomous production systems. Introducing PLCs to secondary school students, taught through an effective teaching model poses the challenge of choosing an appropriate programming environment, among other things. Our study involved a total of 87 students from five participating EU countries in the first phase to analyse practical issues of introducing PLCs into the curriculum and to determine how students perceive textual vs. iconic programming. In the second phase we engaged 40 students from Slovenia alone. We implemented the content in relation to PLCs, implying a competence-oriented teaching model based on transdisciplinarity, constructivism and "learning to learn". Within this learning process, we compared the efficiency of typical textual and iconic programming environments based on problem-solving tasks set for the students. The PLC curricula of five countries are comparable, although the practical implementation of programming environments varies among schools. However, students perceive iconic environments more easily than textual environments. In the second phase, students solved certain tasks in an iconic environment faster. We are aware that our results cannot be generalised. The implementation of our teaching model in emerging programming environments as well as other areas is the predominant challenge for further research.

**Keywords:** contemporary technologies; programmable logic controllers; textual and iconic programming; upper secondary technology education; learning to learn

**Caroline Crockett, Cynthia J. Finelli, Matt Demonbrun, Kevin A. Nguyen, Sneha Tharayil, Prateek Shekhar and Robyn S. Rosenberg** 420–432 Common Characteristics of High-quality Papers Studying Student Response to Active Learning

Active learning is increasingly used in engineering classrooms to improve student learning and engagement. Although students tend to respond positively to the introduction of active learning, some instructors experience negative student responses. Determining why and how to alleviate such negative responses is an open research question. Because there are many contextual variables to consider, we believe this question will best be addressed by increasing the number of faculty who are able to study their own implementation of active learning. This paper examines the underlying characteristics of 27 high-quality papers on student response to active learning. Using a six step research framework, this paper: (1) discusses common categories of research questions, (2) offers rules of thumb for literature reviews, (3) provides example theories, (4) discusses the data collected by qualitative, quantitative, and mixed methods studies and how the data is analyzed, (5) points to different approaches for data presentation, and (6) lists elements which authors typically include in their description of context and discussion sections. We offer literature-driven recommendations for faculty to help them quickly adopt good practices for how to share evidence based on their experiences.

**Keywords:** active learning; student response; systematic literature review

**Runar Unnthorsson and Gudmundur V. Oddsson** 433–445 Evaluating Team Performance in a Student Led Multidisciplinary Project Course with the PAINTER Method

The authors have developed a methodology for teachers to help them to evaluate the performance of a team of students in engineering project-based courses. The methodology was given the name PAINTER and in this paper we demonstrate it with a case study. We use PAINTER to evaluate an engineering project-based course – Formula Student/Formula SAE. The course has been run for 10 years and has the same objective every year – to improve the last year's design. The performance of the team – measured by the score received at competitions – has been around the same level all the years. Efforts taken by teachers to improve the performance of the team have ended in vain. The results show that by using the methodology teachers get a good understanding of potential issues preventing the team from advancing. PAINTER is a relatively easy to use, yet powerful, tool that can be systematically used to identify performance issues. Using PAINTER each factor must be evaluated and scored using reasoning – this systematic approach results in good understanding of the team's dynamics. PAINTER makes issues more prominent and helps the user to decide which issues need to be explored. Although PAINTER was designed for evaluating team of students it is a tool that should be useful for evaluating the performance of other types of teams, e.g., in industry.

**Keywords:** performance; team; students; evaluate

**Elena Bartolomé, Ignasi Florensa and Marianna Bosch** 446–460 Teaching Strength of Materials through "Study and Research Paths": Invariants and Differences

Study and Research Paths (SRP) are general inquiry-based instructional formats, grounded in the Anthropological Theory of the Didactic (ATD), that have been recently shown great potential for teaching Engineering subjects. The SRP is triggered by a generating question ( $Q_0$ ) that gives rise to a sequence of questions-answers, and combines moments of study and moments of research. In this work, we analysed four SRPs Implemented on a Strength of Materials course initiated by two different  $Q_0$  questions, revolving around a slatted-bed (2015, 2018) or a kart (2016, 2017), so as to investigate the invariant and different features between SRPs as a function of the  $Q_0$  and the course edition. Our results allowed us to establish the influence of the generating question and the community of study on the development of the SRP, in terms of the generated questions-answer (Q-A) maps, the resources mobilised, the media-milieu dialectic, and the adaptation of the students and the teacher to the instruction format. In every SRP edition, certain repeated sub-questions related to the strength-stiffness of prismatic bars under different loads appeared, associated to the epistemological conception of the subject, and were tackled combining similar analytical and simulation techniques. However the investigation of the  $Q_0$  often surpassed the traditional limits of the SM subject and implied the study and interconnection of notions related to other areas and the use of novel techniques. The comparison of SRPs started by a different  $Q_0$  revealed however differences in the Q-A maps: the "slatted-bed" SRP was simpler and more directly connected to traditional SM topics, whereas the "kart" SRP implied the study of a larger number of parts, some of them with complex shapes, and implied simplifications. The analysis of several SRP editions with similar  $Q_0$  showed how the *media-milieu* dialectic and the group of students affect the development of the SRP. The SRPs initiated by the same  $Q_0$  displayed a certain common Q-A map skeleton. However, in those editions where the study community adapted better to the SRP device, the Q-A arborescence was richer, and a larger variety of resources and validation forms were employed.

**Keywords:** inquiry-based; project-based learning; anthropological theory of the didactic (ATD); strength of materials; study and research paths (SRPs); engineering education; strength of materials

**Guido Charosky and Ramon Bragós** 461–470 Investigating Students' Self-Perception of Innovation Competences in Challenge-Based and Product Development Courses

This study analyzes self-perception in innovation competences development in engineering students with the objective of understanding how to better design educational strategies to improve innovation skills in future engineering graduates. The INCODE (Innovation Competences Development)-Rubric 5 survey is used to compare two groups of engineering students from Telecom Engineering school from UPC (Technical University of Catalonia) going through two types of project-based courses: CBI (Challenge Based Innovation) course versus PDP (Product Development Project) course. CBI is an innovative learning experience

carried out by three institutions: Telecom Engineering School of UPC, ESADE Business School and IED Istituto Europeo di Design in collaboration with CERN, where mixed teams of students from the three institutions face open innovation challenges through Design Thinking, with the objective of designing solutions to complex societal problems, considering the use of CERN technologies if suitable. PDP is the “standard” capstone course taken by Telecom engineering students following a classical project-management approach. Results show that both courses give a good self-perception of the learning outcomes in the innovation-related skills, according to what is observed in the INCODE surveys’ results when comparing CBI and PDP. The differences found between CBI and PDP are small and only moderately deviated towards CBI in the individual competences dimension.

**Keywords:** innovation competences; challenge-based education; project-based learning; self-assessment

**Sandra M<sup>a</sup> C. Pinheiro, Karla Oliveira-Esquerre, Márcio A. F. Martins and Roseline Oliveira** 471–481 Student Performance in First-Year Math and Physics Courses as Predictor of Student Dropout in Engineering Programs

The dropout rate in higher education institutes has been the subject of constant discussion. This study investigates the dropout rates of engineering programs in the initial semesters, adjusting risk models to potential academic factors. The main subjects of mathematics and physics in the initial semesters are identified and ordered according to level of dropout risk, which can assist administrators in taking actions to improve student performance. The sample consists of 4,848 students in engineering programs at a federal university in Brazil. Failure levels reached 52.3% in first-semester courses and 57% in second-semester courses. The risk calculation identified the main courses that encourage dropout in engineering programs in the initial semesters. Analytical Geometry, Calculus I, Calculus II and General Physics I courses presented high risks for dropout for all the engineering programs. Students who studied analytical geometry showed that the risk of dropout as a result of failure in Calculus I decreased from 19.3% to 6.3%, and in General Physics I the risk decreased from 10.4% to 4.8%. This shows that improving performance in at least one course in the initial semester considerably reduces the rates of dropout from programs.

**Keywords:** dropout rates; failures; 1st- and 2nd-year; poor performance; survival models; risk rates

**Mohammad Alsager Alzayed and Scarlett R. Miller** 482–496 Factors Influencing Undergraduates’ Selection of an Engineering Discipline: A Case Study

The objective of this study was to investigate the factors that predict a pre-engineering student’s first choice of engineering major during their application in an entrance-to-major (ETM) process, admittance into their first choice of engineering major during ETM, and enrollment in the admitted engineering major the semester following the ETM process. The influence of the following factors was explored: gender, age, ethnicity, state residency, year of application, transfer credits, GPA, first semester credits, and cumulative credits. Admissions and enrollment data were collected from three pre-engineering student cohorts from a large public northeastern university in the United States; the sample population of the study included 4,664 students. Astin’s input-environment-output (IEO) model was used as a theoretical framework to model the findings. The results highlighted the impact of gender and ethnic differences on the selection of an engineering discipline in the ETM process. Our model also highlighted the role of the number of credits attained and year of application on students’ selection and commitment to an engineering discipline. The results presented in this case study call for the importance of understanding the heterogeneity amongst engineering disciplines and urges for institutional action through high school counseling and college academic advising that could increase the alignment of student profiles with their career aspirations.

**Keywords:** first year; engineering fields; baccalaureate institutions; diversity; gender; race/ethnicity

**Teirra K. Holloman, Jeremi London, Walter C. Lee, Crystal M. Pee, Chaneé Hawkins Ash and Bevlee Watford** 497–511 Underrepresented and Overlooked: Insights from a Systematic Literature Review about Black Graduate Students in Engineering and Computer Science

Engineers and computer scientists with advanced degrees play a critical role in addressing complex societal challenges while serving as role models for undergraduate students pursuing degrees in these areas. However, the results of a literature map, conducted as a part of a larger study, suggest that we tend to focus on undergraduate education when discussing how to diversify the talent pool. This paper presents the findings from a systematic literature review on the barriers to graduate-level participation in engineering as experienced by African Americans, one of the most underrepresented groups. Twenty-two articles resulted from the search, 11 passing the quality check. The analysis focused on synthesizing themes surrounding how researchers study the problem, barriers to participation, and recommendations for addressing them. Results highlight that investigators tend to focus on three topic areas: (1) Student Identity, (2) Recruitment and Persistence, and (3) Students’ Perceptions of Graduate School. This synthesis presents the current state of the literature on broadening participation of African American engineering graduate students and highlights opportunities for future inquiries.

**Keywords:** African American; graduate students; engineering; computer science

**Yasutaka Ueda, Itaru Kourakata, Nozomu Tsuboi and Takamasa Suzuki** 512–527 Multicultural and Multi-disciplinary Project-based Learning with Industry Focus: Fostering Globally Competent Engineers

Multi-cultural and multi-disciplinary project-based, internship-based learning with real industrial problem-solving has been predicted to enhance global engineers’ competencies; however, less discussion has been devoted to learning practical effectiveness. The Global Dormitory (G-DORM) project, a bilateral student exchange project organized by Japan’s Niigata University in collaboration with four universities from the lower Mekong countries of Cambodia, Laos, Thailand, and Vietnam, developed a pedagogical approach that included such an internship for fostering the growth of global Sci-tech leaders. This paper discusses the effectiveness of – and challenges in – using the G-DORM approach to enable students to enhance the following competencies: (1) generic skills for working in industry; (2) global competencies for engineers; (3) capacity for solving regional revitalization issues using an integrated standpoint; and (4) interests in the industry. This study’s analyzed data were extracted from the questionnaire responses of 82 students who participated in this internship in the Japanese academic year 2018–2019 and from the questionnaire responses of selected hosting companies. The study results emphasized that G-DORM approach-based internships could positively affect students’ competence with regard to global engineering, especially through the designing of stepping-up programs aimed at developing competence. Furthermore, the study results suggested the optimization of internship periods, pre-studies, intervention by moderators during internships, and improvements in post-studies as challenges for future works. We believe that the G-DORM approach has the potential to contribute toward improving industries in lower Mekong countries by aiding in solving their industrial issues through education and fostering globally competent engineers in these countries.

**Keywords:** multi-cultural; multi-disciplinary; project-based learning; internship; global competencies

**Stephen O. Ekolu** 528–536 Model for Predicting Summative Performance from Formative Assessment Results of Engineering Students

The present paper proposes a new model for predicting the summative assessment marks (SAM) of engineering students based on their formative assessment marks (FAM). Often, instructors at higher education institutions have to provide learning to very large class sizes. Therefore, different approaches are sought to alleviate such constraints. One of the recent interests is the possibility of using FAM results to estimate or predict summative performance of students.

In this study, a model was developed using data of modules lectured to undergraduate civil engineering students over a period of 10 years. The data sets used consisted of 18 assessment events of various modules involving 852 students. The linear and power

type models were formulated through data fitting and validation. Statistical error indicators showed the power function model of the form  $SAM = P(FAM)X^Q$  with  $P = 3.2$  and  $Q = 0.7$  to be superior, as the model gave realistic predictions.

**Keywords:** prediction model; formative; summative assessment mark; semester mark; examination

**Nathaniel J. Hunsu, Adurangba V. Oje, 537–549** Examining Factorial Validity Evidence for the Academic Resilience Scale in an Engineering Learning Context  
**Peter H. Carnell and Nicola W. Sochacka**

Research suggests that resilience plays a fundamental role in students' ability to navigate academic adversities and the setbacks they cause. Whether students overcome difficult academic situations and succeed in spite of the academic risk factors they encounter depends on how academically resilient they are. In light of the relevance of academic resilience to students' educational experiences, being able to validly and reliably measure academic resilience has important diagnostic, empirical, and evaluative implications. This instrument validation study re-evaluates the reliability and construct validity support for the recently developed Academic Resilience Scale. Participants were 596 engineering students who completed the Academic Resilience Scale survey. Exploratory and confirmatory factor analyses were conducted to determine the factor structure of the scale and evaluate indicators of the construct validity of its sub-scales. The study proposed that a three-factor model of the instrument that comprises 18 items was preferable to the original 30-item scale proposed by the developer.

**Keywords:** academic resilience; academic resilience scale; resilience; validation study; factor analysis

**Jac K. L. Leung, Samuel K. W. Chu, Ting 550–563** The Impact of Blended Design-Based Learning for Multidisciplinary Cornerstone Design on Students' Motivation in Engineering  
**Chuen Pong and Paul D. Lavigne**

This paper describes our attempt to implement and examine an innovative approach in the First Year Cornerstone Engineering Design Project Course (ENGG1100) offered at the Hong Kong University of Science and Technology. The integration of blended learning and design-based learning approaches creates a more accessible environment in terms of online resources, interaction with instructors and collaborations in the makerspace. The significance of this study is positioned to inform engineering educators of a potential avenue to formulate a scalable yet hands-on and multidisciplinary design experience in the first-year engineering curriculum. Quantitative and qualitative results were collected and analyzed from two consecutive terms Fall 2018 ( $N = 59$ ) and Spring 2019 ( $N = 34$ ), which examined the changes in students' motivation in engineering and elicited their perceptions towards the course. Pre/post comparisons from the survey shows an increase of students' interest towards engineering and their perceived competence after taking the course, but indicated no significance in students feeling less pressured in studying engineering. Five positive themes and two negative themes emerged from analysing responses in the focus group interviews. Many students appreciated the involvement in an open-ended, multidisciplinary design project, recognized the advantages of blended modules, and valued the proximity with instructors. However, some expressed concerns when adapting to the online learning platform and encountered complications arose from working in teams. Work is ongoing to explore ways to expand the breath of engineering disciplines which students can be exposed to in this cornerstone experience, at the same time offering to more first year students by scaling up the class size without losing sight of the authenticity and enthusiasm of the design project.

**Keywords:** blended learning; design-based learning; first-year engineering; cornerstone design; motivation

**Aharon Gero and Itschak Shlomo 564–572** Promoting Systems Thinking in Two-Year Technology Students: An Interdisciplinary Course on Medical Ultrasound Systems

The development of systems thinking is a primary goal of engineering and technology education, especially within the framework of Industry 4.0. While many actions are being taken to promote systems thinking among engineering students, the efforts to advance it among students in two-year technology programs are relatively few. With the objective of promoting systems thinking among electronics students at a two-year college, a unique course on medical ultrasound systems was recently developed. This interdisciplinary course combined physics, electronics and medicine. The study described in this paper characterized, using both quantitative and qualitative tools, students' attitudes toward the course and changes in their systems thinking. Seventeen electronics students in their second semester of study participated in the research. Results point to a significant improvement in students' systems thinking. As to attitudes toward the course, students believe that the course raised interest, advanced systems thinking and contributed to their professional development, but also increased the academic workload immensely.

**Keywords:** systems thinking; interdisciplinarity; two-year colleges; students' attitudes; ultrasound systems