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Section I

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Our research investigates the developing academic identity of engineering academics within the Australasian Association for Engineering Education (AAEE) community. This paper draws on data from interviews with nine 'emerging' authors with a first degree in engineering, from three types of Australian universities where they discuss their 2012 AAEE conference paper and the peer reviews of their paper. Identity-trajectory was used to analyse interview transcripts by focussing on the various elements of this framework of academic identity development. The findings and discussion focus on those aspects of the reviews and the authors' circumstances that appear to either enable or constrain their development as engineering education researchers. The study finds that authors belonging to a discipline-based educational research group made substantial changes to their papers before final submission and we argue that these research groups support these authors in developing their academic identity as an engineering education researcher.

Keywords: peer review; engineering education research; engineering education researcher; academic identity

Junaid A. Siddiqui, Cheryl Allendoerfer, Robin S. Adams and Bill Williams	2352–2377	Integration of Scholarship: Interconnections among Three Studies on Becoming an Engineering Education Researcher
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This paper looks at the process by which scholars became active in and their perspectives evolved for engineering education research (EER). We use a soft systems methodology to bring together findings and insights from three separate studies investigating pathways and experiences of EER in which the authors have been active: two focusing on US scholars and one on international scholars. Despite the broad range of national and international contexts and theoretical frameworks underlying each study, the three can be connected through the lenses of identity, personal transformation, and social learning system. This provides a more comprehensive, complex, and refined picture of the phenomenon of becoming an engineering education researcher that emphasizes the importance of relationships and community interactions, the development of an interdisciplinary identity, and the ways in which these support personal transformation. Practical implications include conferences and institutions encouraging educators to become EER scholars and the need to establish support systems for the purpose.

Keywords: engineering education research; scholar pathways; identity; community of practice; transformative learning; soft systems methodology; scholarship of integration

The understanding of quality in scientific work is fundamental and determines what researchers judge to represent reliable knowledge in their field. Although quality criteria are used daily in research, there are few extensive discussions available especially in Engineering Education Research (EER). For the development of future high-quality research in EER we argue that it is necessary that the EER-community begin to negotiate criteria for quality. In this paper we propose tentative criteria with a special focus on qualitative EER, although we argue that several of our proposed criteria are also appropriate for quantitative EER.

Our proposed criteria are divided into three main categories: quality of a study in general, quality of the results and validity of the results. We describe these in detail, together with a number of subcategories for each and introduce a hypothetical study to exemplify our criteria. It is stressed that the proposed criteria are tentative and that criteria need to be open for debate and need to evolve as research evolves.

Keywords: engineering education research; research quality; quality criteria

Elliot P. Douglas, Jack Vargas and Claudia Sotomayor 2395–2400 Student Construction of Knowledge in an Active Learning Classroom

Active learning approaches are becoming of increasing importance within engineering education, and it has been established that an active learning environment leads to improved student outcomes. What are less known are the ways in which these classes support student learning. Our study takes place in the context of a Process Oriented Guided Inquiry Learning (POGIL) classroom. We use grounded theory to answer the research question: How do students construct knowledge in a POGIL classroom? Constructivist grounded theory was used to code student interview data and develop a theory of how student learning occurs. The resulting theory shows that the use of POGIL results in a concept-focused class, as opposed to focusing on discrete aspects of knowledge (facts). This concept-focused class provides for both conceptual understanding and improved retention of information. The findings illustrate one way to design a class for deep conceptual understanding and suggest broader implications for curriculum design.

Keywords: POGIL; guided inquiry; active learning; grounded theory

Syed Ahmad Helmi, Khariyah Mohd-Yusof and Fatin Aliah Phang 2401–2414 Enhancement of Team-based Problem Solving Skills in Engineering Students through Cooperative Problem-based Learning

This paper presents a study of the enhancement of team-based problem solving skills among engineering students who undergo Cooperative Problem-Based Learning (CPBL) in an engineering course. The design of the CPBL framework aims to promote team-based learning and enhance problem solving skills. The CPBL cycle and engineering problem solving cycle entail four stages of development: build, bridge, extend, and apply. The study examines this transformation of learning maturity, from novice to expert, using quantitative methodology. Based on pre and post-tests, utilizing quantitative instruments, which are the Engineering Problem Solving Instrument and Team-Working Effectiveness Score, the results show that students significantly enhanced their team-based problem solving skills.

Keywords: engineering education; team working; problem solving skills; cooperative learning (CL); problem-based learning (PBL); cooperative problem-based learning (CPBL)

Jane Andrews and Robin Clark 2415–2425 A Community Based Participatory Research Study into Why Some Girls Don't 'Do' Engineering

One of the main issues faced by British Society today is reflective of the fact that there is a documented shortage of young people selecting a career in engineering. This is particularly the case when it comes to young women, many of whom simply don't consider engineering to be suitable for women. The reasons for this are well documented but are undoubtedly worsened by the fact that only 6% of UK Engineers are female. Taking into account previous studies focusing on the issues of gender in engineering, a community based participatory research approach was adopted in which the reasons why teenage girls fail to view engineering as a viable future study or career option were explored. Two 17 year old female high school students were trained as participatory researchers and employed to conduct semi-structured interviews with their peers. A thematic analysis of the data was undertaken whereupon two distinctive themes emerged in relation to how girls' perceive engineering. The first theme reflected girls' lack of knowledge about what engineering is, whilst the second was related to their views of engineering as a potential career. Verbatim quotes are used throughout the paper to give the teenage participants a previously unheard 'voice' in the debate about gender and engineering. The paper concludes by arguing that although engineering has much to offer young women in terms of a potential future career, the main issue is that they lack awareness of what engineering is and what engineers do.

Keywords: gender issues; engineering; participatory research; teenage girls

Aini Nazura Paimin, Roger G. Hadgraft, J. Kaya Prpic and Maizam Alias 2426–2433 An Application of the Theory of Reasoned Action: Assessing Success Factors of Engineering Students

Student attrition in engineering is of concern. This study investigated motivational factors necessary to succeed in engineering. The Theory of Reasoned Action (TRA) model was used to guide the suggested paths from learning strategy, interest, and intention to academic performance. Participants were 135 Malaysian and 132 Australian engineering undergraduates who had completed the Study Process Questionnaire (R-SPQ-2F) scale and the Learner Autonomy Profile (LAP-SF) scale. The correlation coefficient analysis showed strong interrelationships between learning strategy, interest and intention. The findings of the structural equation modelling (SEM) revealed unexpected but interesting findings between the two countries. Two different pathways were established for the Malaysian and Australian data suggesting that the TRA model is best suited to the Australian learning context. The findings of this study could help identify a suitable model for explaining success factors in engineering.

Keywords: cognitive; affective; conative; academic performance; Theory of Reasoned Action; success

Soheila Firouzian, Hamidreza Kashefi, Yudariah Mohammad Yusof, Zaleha Ismail and Roselainy Abdul Rahman 2434–2445 Mathematical Competencies as Perceived by Engineering Students, Lecturers, and Practicing Engineers

Mathematical competencies (MCs) are essential for engineering students to be competent and qualified engineers after graduation. The term mathematical competence refers to the ability to understand, judge, do and use mathematical concepts in relevant contexts and situations, which is the predominant goal of mathematical education for engineers. This paper will discuss the required MCs of engineers at the workplace as compared to acquired MCs of engineering undergraduates and also the difference in expectation of engineering lecturers from engineering students at graduation. A qualitative approach was used to investigate the required, acquired and expected mathematical competencies as well as the mismatch between these competencies. Semi structured interviews were carried out to collect data from 20 engineers, 41 engineering students and 4 engineering lecturers. The findings indicated that there were differences between the perceptions of acquired and the required MCs. The results showed that there is a need to review the focus of engineering mathematics curriculum to prospective engineers taking into account the attainment of mathematical competencies. These competencies need to be included as explicit learning outcomes in addition to the development of mathematical concepts, aptitude and skills.

Keywords: acquired mathematical competencies; engineering education; outcome-based education (OBE); required mathematical competencies

Section II

Catherine E. Brawner and
Catherine Mobley

2446–2459 Advising Matters: Engineering Transfer Students' Transition Experiences
at Five Institutions

This study identifies challenges that engineering transfer students may face as they transition from one institution to another while pursuing their undergraduate degrees and explores ways institutions can address and potentially mitigate these challenges. We interviewed 86 engineering transfer students at five institutions in the US to identify policies and practices that can be employed to improve the transfer process. The results reveal two themes within the control of universities and engineering colleges that contribute to the ease or difficulty of transferring to these institutions. The first theme, *transmitting information*, includes advising, orientation, mentoring, and websites for engineering transfer students. The second theme, *policies and processes*, includes formal transfer programs (e.g., 3+2 programs), relationships with key feeder schools, admissions, and accepting transfer credits. We conclude that online and in-person advising that takes place during the pre-transfer, pre-enrollment, and first term of the student's transition is critically important to a successful overall experience in the new institution. Students experienced challenges with the unexpected delays associated with formal transfer programs, such as 3+2 programs; administrators should ensure that students enrolled in these programs graduate in a timely fashion.

Keywords: transfer student; advising; orientation; transfer policies; MIDFIELD

Aharon Gero, Yinnon Stav and
Netanel Yamin

2460–2469 Increasing Motivation of Engineering Students: Combining “Real World”
Examples in a Basic Electric Circuits Course

Literature indicates that electrical engineering students show little interest in the basic electric circuits course. Most of the students see it as a technical course, which does not provide an in-depth understanding of the discipline of electrical engineering. The Department of Electrical Engineering at the Technion—Israel Institute of Technology has decided to integrate into the course examples reflecting the diverse areas of study the Department offers and the various fields of practice in which electrical engineers are employed in the industry. The integration of the examples was designed to increase students' interest in the course in particular and in electrical engineering in general. Using quantitative and qualitative tools, the study described in the paper set out to examine the effectiveness of the proposed approach and check whether there was a difference in the motivation toward the study of electrical engineering between students who participated in the course in its new format (with examples) and that of students who participated in the course in its original format (without examples). One hundred and twenty three sophomore electrical engineering students took part in the study. The findings indicate a significant gap between the intrinsic motivation of students who attended the course in its new format and that of their peers.

Keywords: engineering education; motivation; basic course; electric circuit theory

Kenneth J. Reid, P. K. Imbrie, Joe J. J. Lin, Teri Reed and **Jason C. Immekus**

2470–2486 Psychometric Properties and Stability of the Student Attitudinal Success
Instrument: The SASI-I

The Student Attitudinal Success Instrument (SASI-I) was designed to collect data on affective (non-cognitive) characteristics for incoming engineering students (a) which can be collected prior to the first year and (b) for which higher education institutions may have an influence during students' first year of study. Three years of data from incoming first-year engineering students (N = 5,181) were collected and analyzed. This work focuses on two research questions: Do the scale scores of the instrument demonstrate evidence of reliability and validity, and what is the normative taxonomy of the scale scores of first-year engineering students across multiple years?

Internal consistency of scale scores was investigated. Factor analysis was used to establish and verify the structure of the factors and subfactors. McDermott's three-stage cluster analysis was used to define the normative taxonomies of three years of student data. The SASI-I is shown to be a psychometrically sound instrument for the population of first-year engineering students at a Research 1 institution: Cronbach's coefficient alpha values for all scales exceed 0.8 (with two exceptions, 0.75 and 0.79); confirmatory factor analysis results verify the theoretical factor structure of each. Cluster analysis results in a stable, repeatable 3-cluster solution over multiple years: clusters expected to be highly similar were shown to have values of Cattell's coefficient > 0.94. In addition, normative taxonomies in the form of cluster membership establish this work as a foundation upon which future retention research can be performed.

Keywords: first-year engineering; first-year student success; psychometric analysis; quantitative instrument; affective characteristics

Courtney Faber, Penelope Vargas and
Lisa Benson

2487–2500 Engineering Students' Epistemic Cognition in a Research Environment

Undergraduate research experiences provide students the opportunity to solve complex, open-ended problems in their fields. As such, it is expected that these opportunities influence students' development of problem-solving skills and beliefs about how knowledge is constructed in their fields. This exploratory study utilized a qualitative approach to understand how students acquire, understand, and justify knowledge (epistemic cognition) within an undergraduate research experience in biomedical engineering. We interviewed six undergraduate biomedical engineering students with diverse research experiences. Transcripts were analyzed using an iterative process that employed emergent and a priori coding using previous work in epistemic cognition as a lens. Our analysis revealed that many of the processes students use when selecting a research topic and making research decisions aligned with processes that are commonly used in the field of biomedical engineering, representing students' integration into the community of practice and adoption of the community's epistemic processes. Our results suggest that students' time in research, personal goals, research group culture, and the nature of the research project impact the processes students use to make research decisions. Four emerging researcher profiles (novice, passive, developing, and contributing researcher), based on students' time in research, autonomy in the lab, and use of research heuristics emerged from our data. The results of this work can inform the development of authentic problem-solving environments, such as research experiences and inquiry activities that aim for students to develop the epistemic practices of a specific community.

Keywords: epistemic cognition; undergraduate research experiences

Jacqueline K. Burgher, David M. Finkel, Bernard J. Van Wie and **Olusola O. Adesope**

2501–2516 Implementing and Assessing Interactive Physical Models in the Fluid
Mechanics Classroom

In this study miniaturized physical models were used that consist of a base unit and two fluid mechanics cartridges in a junior-level chemical engineering classroom (N = 38). The implementation was structured using Bloom's taxonomy to characterize modes in which concepts were presented and learned by the students and the learning evaluated from an ICAP hypothesis (Interactive, Constructive, Active, Passive) perspective, Anderson's Information Processing Theory, and cognitive load theory. Pre-and post-tests in the form of quantitative assessments were administered after implementation with a passive control group and an interactive group using physical models. Findings indicate the interactive group achieved larger learning gains when paired with higher-level Bloom's activities, with three assessment questions showing statistical significance. These results indicate that interactive pedagogies linked with higher-level Bloom's activities help students store information in their long-term memory better than passive pedagogies. Additionally, results support the ICAP hypothesis because the interactive sessions lead to higher learning gains than a passive session. Primary conclusions are that students who engage in high interactivity concepts achieve learning gains when the instructional design is paired with higher-level Bloom's activities. Conversely, when students are presented with lower level concepts that have high element interactivity they show no difference in learning gains at lower Bloom's taxonomy levels. The collective

evidence supports a specific niche for the use of physical models in interactive environments where student learning of high interactivity concepts is paired with higher-level Bloom's activities.

Keywords: physical model; ICAP hypothesis; information processing theory; cognitive load theory; hands-on learning

Zeljko Stojanov, Dalibor Dobrilovic and Tamara Zoric 2517–2530 Solving Problems in a Physical Laboratory for Computer Networks and Data Security: A Conceptual Framework with Students' Experiences

Professional engineering practice requires engineers capable for solving real problems, putting problem solving skills in the focus of contemporary engineering education. Identification, systematization, evaluation and reuse of students' experiences in problem solving are necessary for assessing and improving educational processes. Due to the high importance of computer networks and data security for contemporary business, practical experience in physical laboratories is essential for educating engineers for challenges in engineering workplaces. This article presents a study aimed at exploring students' problem solving experiences in a physical laboratory for computer networks and data security. The study is based on qualitative research methods, resulting in a conceptual framework that describes students' problem solving experiences. The framework presents identified types of problems and effects of problems solving for students. The problem types relate to the complexity of scenarios prepared for the laboratory, setting up and configuring laboratory equipment, and configuring and using a variety of software tools. Effects of problem solving relate to learning to use different sources of information, learning through joint work and sharing experiences, learning from more experienced colleagues and learning skills that exceed the learning goals. Benefits, implications and outcomes of the research for students, lecturers and researchers are discussed, together with the limitations and further research directions.

Keywords: students experience; problems solving; physical laboratory; data security; computer networks security; qualitative study

K. Giridharan and R. Raju 2531–2542 The Impact of Experiential Learning Methodology on Student Achievement in Mechanical Automotive Engineering Education

This research work was conducted over a two year period. The independent variable was experiential learning methodology and the dependent variables were students' academic performance, students' attendance and its impact on employability skills/attributes based on students' feedback. 144 undergraduate mechanical engineering students formed the sample and were divided into control and experimental groups. In this work, low-budget working models were developed and used to teach an undergraduate course within a mechanical engineering degree. Two different teaching strategies, one with traditional lecturing methodology for control group and the other with experiential learning methodology for experimental group were adopted. The statistical analysis showed that the experimental group performed significantly better than the control group with respect to 'class pass percentage' and 'grade score'. On comparing the 'class attendance', significantly higher class attendance was achieved in the experimental group compared to the control group. Based on the end-of-semester students' feedback, it was established that the present experiential learning methodology had provided positive influence on students' employability skills/attributes. This study demonstrates the efficacy of experiential learning methodology in enhancing students' learning outcomes. The significance of providing multisensory approach to teaching through hands-on learning experiences is highlighted in this study.

Keywords: teaching methodology; working models; experiential learning; mechanical engineering education; students' achievement

Loralyn Greene, Kimberly Ellis, Dale Masel, Leily Farrokhvar, Michael Ogle and Eileen Van Aken 2543–2555 A Program to Engage College Students in the Material Handling and Logistics Industry

This paper describes the use of a targeted event, Material Handling and Logistics Classroom Day, to enhance appreciation, knowledge, and interest in the fields related to material handling and logistics. Classroom Day is designed to provide engineering, technology, and business students with an opportunity to participate in a material handling and logistics tradeshow, network with other students and professionals, learn about the industry, and apply knowledge gained at the tradeshow to a case study design competition. The purpose of this study is to evaluate the effectiveness of Classroom Day, which includes multiple experiential activities. The hypothesis is that Classroom Day will enhance student appreciation, knowledge, and interest in the field of material handling and logistics. A survey instrument is used to assess outcomes from the perspective of the 160 student attendees. Student survey results show that Classroom Day, as a targeted experiential learning event, increased student appreciation, knowledge, and interest in the field of material handling and logistics. A similar approach may be adapted by other engineering education disciplines to engage students and attract talent to related industries.

Keywords: experiential learning; material handling and logistics; engineering education; tradeshow

Enrique Justo, Antonio Delgado, Manuel Vázquez-Boza and Luis A. Branda 2556–2568 Implementation of Problem-Based Learning in Structural Engineering: A Case Study

This paper provides an in-depth exploration of the implementation of Problem-based learning (PBL) in a first-year structures course with 324 students and eight faculty members, focusing on the factors that may increase or hinder its effectiveness. The research follows a qualitative approach by examining a case study to gain insight into the participants' experience. Data were collected from students and faculty through open-ended surveys and focus groups, and analyzed with qualitative data analysis techniques. The outcomes from the evaluation study indicate that the main strengths of the course were teamwork, self-directed learning, continual assessment, practical approach and faculty involvement, while the main weaknesses were the disorientation experienced by the students at the start of the problems and the uneven participation of group members in the group tasks. From our experience, we can conclude that PBL adapts well to a practical approach towards learning structures. The main shortcomings identified have been associated with poor implementation of certain key PBL principles. Improvement actions should be aimed at (a) reinforcing the tutor's role and (b) paying greater attention to the learning process.

Keywords: structural engineering education; problem-based learning; case study; learning in technical disciplines

D. Fernández, F. J. Ruiz, L. Bellido, E. Pastor, O. Walid and V. Mateos 2569–2584 Enhancing Learning Experience in Computer Networking through a Virtualization-Based Laboratory Model

A networking laboratory is an essential tool for teaching communications engineering. However, the effort and cost invested in creating a networking laboratory with physical equipment are significantly high, especially if the students are to work on realistic scenarios. By substituting physical networking devices by virtualized ones, virtualization technologies may contribute to simplify the laboratory management tasks and allow the creation of affordable and more complex network scenarios. In this way, students can work and experiment on realistic network scenarios, so that their learning experience is greatly improved. In this paper a detailed description of a virtualization-based networking laboratory model, evolved over the last 10 years of authors' experience in teaching computer networking, is provided. This laboratory model is implemented using Virtual Networks over linux (VNX), an open source tool specifically designed and developed to define, build, deploy and manage networking scenarios taking full advantage of virtualization, and supporting hybrid virtual/physical scenarios and heterogeneous operating systems. The features of the VNX tool, illustrated with an example of a complex network scenario used by more than 300 students, are described. A survey-based assessment of the usage experience of VNX is included in the paper, showing the validity and efficacy of the proposed laboratory model and of the VNX tool for teaching computer networking in laboratory assignments.

Keywords: networking laboratory; virtualization; Virtual Networks over linux; VNX

Engineering students constitute a large cohort of all students who take first-year physics laboratory at universities. Unfortunately, many laboratory activities that these students perform do not reflect their educational needs and interests. One method of increasing engineering student engagement in physics labs is to blend in elements of design and automation through interesting applications which rely upon the physics principle under investigation. To achieve this blend, suitably flexible hardware and software is required. We present our implementation of such a physics laboratory program for engineers based on the LabVIEW programming language. Details of how students are led to gain experience with LabVIEW throughout the term is presented. Two specific experiments involving Hall switches are detailed.

A survey of 178 students shows that LabVIEW activities introduced in our laboratory are of an appropriate difficulty, and that students find them useful for their educational needs. The survey also shows that students value LabVIEW-based physics exercises significantly more than microcomputer-based labs (MBLs) or traditional labs.

Keywords: physics education; physics laboratory; LabVIEW software; computer-based labs

This study investigates the interplay among design method, technology enhanced learning, and global engineering learning. It presents the process of how a team of engineering educators employed a set of design methods to integrate a variety of learning technologies in order to develop an interactive learning environment, upon which, multiple global engineering courses have been successfully developed. The designers went through a systemic design process of stakeholder involvement, functional design, and conceptual design. As a result, two key functional requirements of the interactive learning environment are proposed: (1) connect globally distributed classrooms and (2) promote peer-to-peer interactions among global learners. And two corresponding design concepts are generated: (1) videoconferencing classroom and (2) interactive eLearning system. An evaluation was conducted upon a particular global engineering course, namely “Principles and Practices of Global Innovation”, which was served by 130 students who signed up from six global universities. At the conclusion of the course, an evaluation was conducted to solicit the participants’ satisfaction with the interactive learning environment, and the impacts of this unique technology-enabled global learning experience on their knowledge, skill and attitude of Information and Communication Technology.

Keywords: Keywords: design method; technology enhanced learning; global engineering learning

Globalization has affected the engineering profession and increased the pressure on engineering programs in developing countries to reform curriculum contents and to revolutionize teaching approaches to ensure that graduates can compete in the global engineering market. This article provides a critical overview of the challenges facing Lebanese engineering educational programs in the formation of global engineers and discusses the effects of these challenges on the engineering career. In Lebanon, the curriculum is highly structured which leaves students with limited choice of taking elective or interdisciplinary courses. Moreover, the reliance on a traditional deductive teaching style and the absence of a national accreditation system have been responsible for deficiencies in students’ acquisition of essential professional skills and knowledge for a global and competitive career in engineering. This study provides several implications for engineering education in developing countries, namely about the need to shift focus from teaching content to the development of skills and competencies. A reform initiative that aims at revolutionizing the teaching and learning style is recommended to address the pressing challenges.

Keywords: engineering education; accreditation; globalization; engineering career; Lebanon; active learning; soft skills

Plagiarism committed by international postgraduate students who come from a non-English speaking background (NESB) has been raised repeatedly as a pressing academic concern. In this study, postgraduate engineering students’ views about plagiarism and their ability to detect and avoid plagiarism were examined using a survey instrument. The primary question investigated was whether there was any discernible variation in attitudes and abilities between students from different cultural and linguistic backgrounds. As such, the survey (n=416) was designed to assess students’ ability to recognise and rate the severity of plagiarism in a series of writing samples. The responses were collated by birth country and compared by the major geographic regions represented. All participants were invited to give further insight in a post-survey interview where their ability to correct identified plagiarised work was also tested. The results revealed that there were notable differences between the geographical sub-group students’ ethical stance and their abilities to identify plagiarism. Furthermore, the variation in attitudes and abilities was still evident after at least a semester of postgraduate study. The plagiarism detection exercise indicated that although the Oceania sub-group were better at identifying plagiarised material, the other sub-groups (consisting entirely of students from either a NESB or with English as a second language) were nearly as proficient. Skill deficiencies and language issues, representing potentially significant disadvantage with respect to academic writing, were evident however when these students were asked to correct the identified plagiarised material.

Keywords: plagiarism; postgraduate; engineering; geographical region

Thermodynamics is a particularly challenging course for many engineering students early in their college education. Thus, it represents a significant opportunity for the use of concept inventories to assess students’ understanding of core ideas and principles in order to gauge their initial knowledge and aid their future learning. In this paper we forward an inventory to assess students’ understanding of foundational thermodynamics concepts and principles, such as state relations, heat, work, and conservation of energy, as well as their ability to reason conceptually using this knowledge. A 36-item thermodynamics conceptual reasoning inventory (TCRI) was developed and evaluated. The inventory was reviewed by four external experts and administered to 448 students. This study reports evidence to demonstrate that TCRI scores are a reliable and valid indicator of students’ thermodynamics conceptual knowledge and reasoning ability. TCRI scores show high internal consistency, distinguish between cohorts expected to differ, and correlate with course assessments. The TCRI is recommended for students beginning their study of thermodynamics. Course instructors can use the TCRI as a formative assessment. The TCRI can also serve as an assessment tool for researchers to evaluate the effects of instructional interventions.

Keywords: thermodynamics; conceptual reasoning; concept inventory

Sustainability has been gaining attention worldwide due to rising evidences of environmental problems and societal issues. Tertiary education has responded to the attention by taking a series of initiatives for delivering knowledge of sustainability. Among all, engineering discipline appears to be among the most active in seeking to integrate the components of sustainable development into its curricula. Many researchers have studied the approaches used for integrating sustainability knowledge into engineering education, but most of these studies are only relevant to the European, American and Australian contexts. The relevant information in the Asian context is scant, due to limited published reports or literature on how the Asian universities, including Malaysian's, are integrating sustainability into their engineering curricula. Therefore, this study aims at studying the current approach used by the Malaysian universities to integrate sustainability into its engineering curricula and identifying which approach is more effective for such integration. This study targeted at the chemical engineering undergraduate programme in five selected universities in Malaysia. A survey was used and a total of 173 responses were collected. Correlation analysis was then conducted. It was found that the undergraduates' knowledge and interest level of sustainable development was unsatisfactory. The results revealed that specific and compulsory courses related to sustainable development could be more effective for delivering knowledge of sustainability for the undergraduates, a finding that was different from that suggested in the existing literature for the Western Countries such as the United States, United Kingdom, the Netherlands, Sweden and others.

Keywords: sustainability; education; approach; chemical engineering; knowledge; interest