

The International Journal of Engineering Education

Contents

Part I

Outreach to Prospective Engineering Students

Guest Editors

Kok Kiong Tan, National University of Singapore

Lawrence J. Genalo, Iowa State University

Igor M. Verner, Technion — Israel Institute of Technology

- | | | |
|---|---------|---|
| A. Ibrahim, | 403 | Editorial |
| Kok Kiong Tan, L. J. Genalo and I. M. Verner | 404 | Guest Editorial: Outreach to Prospective Engineering Students |
| R. Jain, B. Shanahan and C. Roe | 405–418 | Broadening the Appeal of Engineering—Addressing Factors Contributing to Low Appeal and High Attrition |

The declining number of graduating engineers necessary for the long-term economic growth and well-being of the US is becoming a serious challenge. We discuss national and international trends towards a decline in engineering enrollment and the consequences of further decline of engineers to the nation; data on a minority of women and persons with disabilities participating in the profession are examined in a historical context and the reasons for their relatively low numbers are evaluated, as are issues and causes related to student retention and low appeal of engineering in American universities. Input from key engineering educators (engineering school deans) has been analyzed and presented to understand the factors contributing to the low appeal of engineering among the general public and high attrition among students. A generalized preference index model is developed to address these two crucial issues; example use of preference indices is also presented. Based upon research and data, strategies are proposed that can be implemented to improve recruitment and retention.

Keywords: Engineering appeal, student recruitment, student retention.

- | | | |
|---------------------------------|---------|---|
| P. Hylton and W. Otoupal | 419–425 | Engaging Secondary School Students in Pre-Engineering Studies to Improve Skills and Develop Interest in Engineering Careers |
|---------------------------------|---------|---|

Academic institutions are finding that creating and maintaining a student's interest in engineering and technology during the secondary school years is critically important. The authors have combined experiences from their previous engineering careers with techniques from their current teaching positions to develop and pilot some new approaches to accomplish this. They were given a unique opportunity to develop a summer enrichment program for students from a large urban school system. The students involved were predominantly minority, were all from low socio-economic status households, and were roughly evenly divided between male and female. These students represent a demographic cross-section that is in short supply in engineering today. They were selected for the program based on assessed potential for success in science, engineering, and technology programs. However, the students showed a significant lack of self-confidence in their abilities to succeed in such careers. Additionally, pre-course testing indicated a shortfall in basic math and science skills necessary for success in engineering. The month long program took the approach of connecting real world applications of simple engineering concepts to the basic skills necessary to analyze those concepts. After three summers of activity, the authors have had the opportunity to construct and deliver several different curriculum modules to multiple groups of students.

Keywords: Outreach, K-12 education, pre-engineering.

- | | | |
|--------------------------------|---------|---|
| D. Sporea and A. Sporea | 426–435 | Outreach Activities for Pre-University School Students Coordinated by the Centre for Science Education and Training |
|--------------------------------|---------|---|

This paper discusses the various means we use in order to assist informal technical education in Romanian pre-university schools, from elementary to high school, in the frames of National and International projects of which we are a part. The activities are run by the Centre for Science Education and Training, which coordinates the 'Hands-on Science—Romania' Educational Network, at National level. Efforts are directed towards promoting different teaching methods (e.g. problem-based learning, science clubs, science fairs, debates) and tools (e.g. computer-based data acquisition, LabVIEW programming, virtual experiments) to develop additional skills and to enhance student interest in studying technical subjects and engaging in engineering careers. Another objective is to involve as much as possible the entire community (students, parents, teachers, local authorities, organizations responsible for teacher professional development) in common activities focused on science teaching.

Keywords: Teaching methods; LabVIEW; pre-university

- | | | |
|---|---------|--|
| S. E. Watkins, M. A. Huggans and S. J. Bentley | 436–443 | Pre-College Outreach at a Technical Conference |
|---|---------|--|

A strong technical workforce is essential in a technology-based society. The selection of science, technology, engineering, and mathematics (STEM) electives and of related careers is influenced by familiarity with and perceptions of engineering. Pre-college students need significant opportunities to interact with engineering professionals and to investigate engineering careers. Also, pre-college teachers can gain insight into engineering through such experiences. Technical conferences attract professionals from industry and academia and showcase technologies. Hence, a conference venue can serve as an enriching environment for a pre-college program. Outreach activities for students and teachers were held at the IEEE GLOBECOM Conference. The participants interacted with conference attendees in selected conference activities and dedicated pre-college events. After the conference, the participants shared this experience at their schools. The assessment examined the effectiveness of the interactions and the appropriateness of selected conference activities. The approach can serve as a model for other conference-based outreach programs.

Keywords: pre-college outreach; K-12 education; STEM careers; engineering conference

S. Amato-Henderson, J. B. Lehman and P. Cattellino 444-451 Outreach to Prospective Engineering Students: Assessing Michigan Technological University's YES! Expo

According to the National Science Board, we must increase interest in STEM education and careers to maintain our position as a global scientific and technical leader. The number of students indicating interest in engineering, engineering related, and computer related fields on their ACT exams has plummeted. Ethnic and gender diversity in engineering continues to be low. In a response to this declining enrollment and interest, Michigan Technological University annually brings together industry, institutions of higher education, governments, and the K-12 education system to offer the annual YES! (Youth Engineering and Science) Expo, a career awareness event at Ford Field in Detroit, Michigan for 15,000 students and 1,500 teachers. Using pre- and post-event surveys to assess the impact of the event, results indicate that the YES! Expo has a significant positive effect on students' educational and career goals.

Keywords: engineering education; self-efficacy; diversity; career goals

S. Thompson and J. Lyons 452-460 Engineering Outreach in Middle School: The Influence of a Long-Term, School-Based Collaboration

This paper investigates the long term involvement of graduate level engineering students in middle school science classrooms and reports the impact on participating graduate students and the middle school students they taught. Four years of pre and post data were collected from a total of 19 graduate students, their research advisors, and over 1200 middle school students. Key findings for the graduate students included enhanced communication, teaching, and research abilities. Key findings for students included enhanced perceptions and understandings of engineering.

Keywords: GK-12; engineering outreach; engineer/teacher collaboration

A. R. Carberry and W. J. Church 461-467 HS-STOMP: High School Student Teacher Outreach Mentorship Program

The High School Student Teacher Outreach Mentorship Program (HS-STOMP) is an outreach opportunity for high school students to flex their knowledge of science, engineering, and technology through a teaching experience. The program is designed as a learning opportunity to deepen and strengthen the high school students' understanding of science, while facilitating the learning of engineering and technology principles for K-8 students and teachers. This paper describes the concept of HS-STOMP, the development of the program, the program in action, and the challenges faced in the three-year evolution of HS-STOMP.

Keywords: outreach; student-teacher mentorship; engineering and technology

E. DeBartolo and M. Bailey 468-478 The TEAK Project: Students as Teachers

The TEAK (Traveling Engineering Activity Kit) Project is a program that involves RIT engineering students in the design, construction, and presentation of creative tools for teaching engineering concepts to middle school students in the Rochester, New York community. The TEAK Project is unique in that the college students involved do not only teach engineering, but they create their own instructional materials, lesson plans, assessment tools, and experimental hardware. The result is that, not only do the middle school students see college engineering students as role models and benefit from the early exposure to engineering, but the RIT students involved in the project gain valuable experience as teachers of engineering.

Keywords: Creative tools, experimental hardware, energy and environment.

G. E. Slaughter and K. Ngandu 479-484 Diversifying Engineering Education for Richmond Area Program for Minorities in Engineering

The Richmond Area Program for Minorities in Engineering Summer Engineering Institute (SEI) consists of comprehensive hands-on activities, and mentoring of women and minority students in the quest to increase the presence, retention and the advancement of girls and minorities in engineering and science. The SEI is a three five-week long endeavor, with multiple engineering-based team projects design to stimulate middle and high school students to consider engineering as a career. Each team is required to make two oral presentations throughout the program: one with their class and the other at the closing ceremony. Family members, school officials, and industrial representatives are invited to campus to celebrate the accomplishments of the SEI participants. As a result of the engineering-based projects, the SEI provides the students with realistic hands on experience that helps them with the transition from theory to real engineering practice. This paper attempts to diversify engineering education while providing a uniform program grounded in a fundamental set of engineering projects and principles.

Keywords: K-12 education; outreach; pre-engineering; summer camps; minority students; engineering; diversity

O. Gleiche, H. Thye, K. Delto and H. Garbe 485-492 Sparking Pupils' Engineering Interest with Laboratory 'TechLab'

The authors claim that the pupils' laboratory TechLab at the Leibniz University Hanover is an answer to pupils' disinterest in technology, the negative image of technology and the insufficient technical education at school. A further aspect for the foundation of the laboratory is the growing demand of engineers, technicians and their educators. The analysis of an engineer's field of activity and the lack of pupils' knowledge is the basis of the concept of the laboratory. For an effective implementation of the concept it is necessary to bring the worlds of school and university together. Thus, the specific characteristic of the laboratory is the teamwork of scientists and teachers on the same level in order to get pupils interested in technology.

Keywords: Sparking interest in technical subjects; pupils' laboratory; collaboration of schools and universities; students supervise pupils

G. L. Winn, D. Lewis and R. Curtis 493-498 Bridging Engineering Education to High School Science Teachers Using TIME Kits

The United States clearly needs more technically qualified undergraduates, particularly engineers. Even though high school students are already heavy users of technology, as often are their teachers, there is a gap in understanding how the technologies are derived, developed, prototyped, tested and evaluated. A National Science Foundation STEP project (Science, Technology, Engineering, and Mathematics Talent Expansion Program) at West Virginia University's College of Engineering and Mineral Resources currently employs a carefully crafted intervention, the TIME kit, as an attempt to cross the divide between high school students and math or science teachers by providing an integrated curriculum using real-life engineering problems with web-based delivery. TIME Kits also employ mandated 21st Century Skills and No Child Left Behind state teacher standards to make them more attractive for teachers to use. Statistical treatment of teacher self-reports are favorable and statistically significant on effectiveness of TIME Kits in the field after two years of teacher training; longer term evaluation of student skill and knowledge change is underway. An exemplary TIME Kit that explores the engineering aspects of Acid Mine Drainage is included in our review.

Keywords: Curriculum; design cycle; university partnership; TIME Kit.

K. Z. Tang, K. K. Tan, Y. H. Goh, A. Tay, S. N. Huang and T. H. Lee 499-510 Development of a Framework and System for Remote Electronics Experiments

The outreach activities organized by the Department of Electrical and Computer Engineering (ECE) at National University of Singapore (NUS) are geared towards bringing interesting engineering projects, workshops, talks and other engaging activities to the students and teachers in the various high schools in Singapore. To expand the scope of the outreach activities, a framework and system to facilitate remote electronics experiments has been developed, utilizing remote virtual instrumentation concepts. Using the proposed

setup, the students are able to design electronic circuits and observelanalyze the responses from the circuits to excitation, while being physically distant from the laboratory where the electronic circuits and instrumentation/measurement systems are located.

Keywords: Remote electronics experiment; virtual instrumentation

G. W. Ellis, K. L. Silva, T. Epstein and N. C. Giammaria 511–522 Artificial Intelligence in Pre-College Education: Learning within a Philosophy of the Mind Framework

In this paper we present an approach for integrating AI and philosophy of the mind in the K-12 classroom. Our rationale for this approach includes its capability to promote discourse and frame learning and the need to take a more holistic approach to engineering. We have developed a curriculum unit based upon the integrated approach that includes intended learning outcomes, a concept map and two example activities for the classroom. We present this curriculum unit together with the preconceptions of middle and high school students related to the concepts in the unit. The collected data shows high levels of interest in the possibilities of thinking machines, but only a naïve understanding of the issues. Some gender differences are also indicated. Finally we present two applications where the curriculum was used in the classroom. The first is a one-week unit in a middle school language arts classroom and the second is a full-year project-based high school course. Results from both settings showed high levels of engagement and were consistent with student achievement of intended learning outcomes.

Keywords: artificial intelligence; philosophy; concept map; preconceptions; pre-college

S. S. Klein 523–533 Effective STEM Professional Development: A Biomedical Engineering RET Site Project

The Vanderbilt University Biomedical Engineering RET Site Project was created through the National Science Foundation's Research Experience for Teachers program with the goals of giving teachers a broad overview of biomedical engineering, engaging the teachers in meaningful research experiences, and helping teachers to take their research experiences back to their high school science classrooms. Forty-four teachers participated in a twenty-four day summer program with academic year follow-up in which they completed a research project in a biomedical engineering laboratory, designed an instructional unit based on that research experience, and implemented it in their high school classroom. As judged by two attitude surveys given to the participants, this RET program seems to have been an effective program for engaging teachers in meaningful research experiences that allowed them to experience and understand the research process, giving them the ability to relate this to their students. Teachers were able to contribute to the overall research goal of their lab and they were able to complete a small project during their tenure in the lab. Teachers were able to develop an instructional unit based on their research experiences that helped them to bring back into their classrooms what they had learned about STEM research. The teachers' self-confidence grew along with their views of the importance of science research in the classroom and their willingness to seek help. The combination of research and structured instructional materials development based on educational research has created a highly effective professional development program for improving STEM instruction in our high schools and meeting the NSF's program goals.

Keywords: high school; professional development; teachers; biomedical engineering

B. Haberman, C. Yehezkel and H. Salzer 534–546 Making the Computing Professional Domain More Attractive: an Outreach Program for Prospective Students

The recent rapid development of the field of computing has posed challenges in educating newcomers, in particular, in attempting to bridge the gap between school and the contemporary world of computing. To meet this challenge, we developed a novel outreach program for prospective high-school students aimed at exposing them "directly by leading experts" to state-of-the-art computing research and development. The program includes enrichment meetings and software development projects under the supervision of experts. Six hundred students participated the last four years in enrichment activities; 86 of these students developed high-level software projects. A long-term formative evaluation of the outreach program has been conducted. So far, the study's findings have indicated that the program contributes to developing a culture of learning befitting the dynamic world of industrial computing, thus providing the students with an entry point into the computing community of practice.

Keywords: Software engineering; project development; mentoring; self-learning; software design skills; scaffolding activities

Part II

Contributions in: Assessment, Collaborative learning, Remote laboratories, Automotive Engineering, Energy management, Mechanical Engineering, and Nanotechnology

K. N. Le, V. W. Y. Tam and L. Tam 547–556 Assessment schemes in engineering courses using spectral techniques

This paper studies assessment schemes with regard to attitudes and understanding in engineering undergraduate and postgraduate courses at Griffith University, Australia. A survey was conducted consisting of eight typical assessment schemes: seminar, open-book mid-semester test, closed-book mid-semester test, problem-based assignment, presentation, multiple-choice question, closed-book final examination and open-book final examination. F-test, Relative Important Indices (RII), and rankings of each scheme are estimated. An additional insight into the student responses is given by using a novel spectral technique of computing the power spectrum of the data. Detailed comparisons are made. Recommendations are given. Further work is also outlined.

Keywords: relative important index; F-test; toward attitude assessment; toward understanding assessment; power spectrum

E. Gómez-Sánchez, M. L. Bote-Lorenzo, I. M. Jorrín-Abellán, G. Vega-Gorgojo, J. I. Asensio-Pérez and Y. A. Dimitriadis 557–568 Conceptual framework for design, technological support and evaluation of collaborative learning

Computer Supported Collaborative Learning (CSCL) aims at promoting active learning and knowledge construction through the interaction with peers, mediated and supported by software tools, which make it very attractive for engineering courses. Despite this, there are not so many successful CSCL scenarios happening on a regular basis. Several CSCL frameworks try to overcome these limitations by providing guidelines either to educators, or software developers or institutions. However, there is a lack of a global understanding of the whole CSCL lifecycle shared among all stakeholders. Here we propose a framework that tries to point out issues and recommendations for all stakeholders along the whole CSCL lifecycle. It considers the influences between the social and organisational context, the learning process designed by the educator, the technology used to support it, and the evaluation of both the process and the technology. We illustrate the usage of this framework with its application to an engineering course on Computer Architecture conceived for a virtual university.

Keywords: conceptual framework, collaborative learning, learning lifecycle, learning technologies.

B. Allen, A. Crosky, I. McAlpine, M. Hoffman and P. Munroe 569–576 A Blended Approach to Collaborative Learning: Making Large Group Teaching More Student-Centred

Current educational thinking promotes a student-centred approach to teaching as more engaging and challenging for students, leading to improved learning outcomes. But what is 'student-centred' learning, and how can it be achieved in a higher education setting with very large classes and content-rich courses? In a materials engineering course for 300 first-year engineers, an online group project was introduced to add authenticity and collaborative activity into the course, and to improve student engagement. We explore the design, development and implementation of the project, and see if the intended outcomes were achieved.

Keywords: Student-centred, collaborative learning, problem-based learning, group work, large group teaching, online

I. M. Michaelides and P. C. Eleftheriou 577–584 Using Engineering Remote Laboratories to Enhance Student Learning—a Distributed Learning Experience

We present our experience of the operation of the solar energy e-learning laboratory (Solar e-lab) in Cyprus, and demonstrate the benefits of distributed learning by employing a remote engineering application. We focus on experientially-based learning which allows remote and distributed training with laboratories, workshops and real working-places over the Internet. The aim of the solar energy e-learning laboratory is to use today's technology as a tool to make laboratory facilities accessible to engineering students (especially handicapped) and technicians located outside the e-lab premises. In this way, the laboratory, its equipment and experimental facilities can be shared by many people, thus simplifying availability and widening educational experiences. Over its four years of operation, users from more than 400 locations in 75 countries have visited the solar e-lab. The results of an online evaluation showed a high degree of satisfaction by the remote students using the solar e-lab. Also, a number of foreign educational Institutions of higher learning have included the solar e-lab in their curricula.

Keywords: Remote engineering, remote laboratories, distributed learning, real world experiments, e-learning, internet, solar energy

F. J. Sánchez, F. Aparicio, M. A. Álvarez and F. Jiménez 585–594 SAE Formula Project for Developing Personal and Professional Skills in Automotive Engineers

Promoting personal and professional skills is becoming an issue of interest and major concern in university environments and this, in turn, is being driven by the demands of business. In this paper the authors present the basic features of the SAE Formula project, an international university competition consisting of designing, manufacturing and competing in formula-type vehicles and analysing to what extent 24 basic skills have been promoted in the students taking part compared with other activities carried out during their Mechanical Engineering degree course.

Keywords: professional skills; personal skills; automotive; engineering education

J. Galindo, H. Climent, J. M. García-Oliver and J. Gimeno 595–602 Cogeneration Workshop for Energy Management Courses by Means of Spreadsheets

A spreadsheet-based workshop has been introduced for teaching energy management. Students have to carry out an energy and economic analysis of the cogeneration facilities. In this paper, the spreadsheet and the different phases of the feasibility analysis are described. Students have to consider different issues, such as the analysis of the energy demand and the choice of prime mover, as well as the operating conditions, and the choice of fuel prices. The workshop has been used in two courses dealing with energy management at both bachelor and master level. The main contribution of this approach is related to the use of spreadsheets to solve complex optimization problems, which were not easy to handle in classroom exercises before the introduction of the workshop. The students' feedback was obtained by means of questionnaires. The evaluation of the students' performance shows that the approach is adequate for them to learn about complex decision-making problems.

Keywords: engineering education; active learning; spreadsheets; energy management; cogeneration

V. Evely and P. Rodgers 603–614 Introducing Mechanical Engineering to Students in the Gulf Region

The design and implementation of introductory courses in engineering have been well documented in Western education, in the context of how engineering education practices must adapt to meet the needs of the twenty-first century. As Gulf students exhibit characteristic strengths and weaknesses, engineering education in this region faces additional, specific challenges that are associated with economical, social and cultural factors. This paper discusses the adaptation in the Gulf region of Western models of engineering introduced to entry-level students, and describes the strategy adopted at The Petroleum Institute to introduce mechanical engineering (ME) to sophomores. Significant blocks of time are devoted to broadening the students' understanding of the ME discipline and profession, fields, tools and practices. The traditional aspects of ME are concisely covered, enabling emphasis to be placed on the petroleum industry and the broader energy sectors, as well as modern and emerging applications of ME. The course structure and teaching methodology focus on developing key professional attributes identified by ABET, promote student involvement and utilize student strengths while tackling characteristic weaknesses in Gulf regional students. After three-semester offering and evolution of the course, it was found that motivated students could demonstrate excellent proficiency in what constitutes mechanical engineering in the twenty first century.

Keywords: Arab, education, engineering, mechanical, gulf

S. Wansom, T. O. Mason, M. C. Hersam, D. Drane, G. Light, R. Cormia, S. Stevens and G. Bodner 615–627 A Rubric for Post-Secondary Degree Programs in Nanoscience and Nanotechnology

Based upon a set of 'big ideas' identified by recent workshops and a study report, a broad curriculum framework has been developed for degree programs in nanoscale science and engineering (NSE). The framework is built around four essential areas or nodes in NSE that include—Processing (how nano-entities are fabricated), Nanostructure (how the structure of nano-entities can be imaged and characterized), Properties (the resulting size-dependent and surface-related properties of nanostructured materials/devices), and Applications (how nanomaterials and nanodevices can be designed and engineered for the benefit of society), which can be abbreviated as 'P-N-P-A'. This paper argues that the P-N-P-A rubric provides a tool for program and course construction and evaluation in higher education. An analysis of emerging NSE degree programs in the US suggests that improvements need to be made in the programmatic balance among the P-N-P-A nodes, with particular attention being paid to essential features such as the interdisciplinarity of NSE and its societal impact (ethics, safety and so on). A significant challenge for achieving programmatic balance is providing students with access to advanced instrumentation, which is an essential element for student mastery of the 'nanostructure' node. Recommendations and challenges for achieving programmatic balance are discussed.

Keywords: Nanoscience; nanotechnology; curriculum design; degree programs; course design