

The International Journal of Engineering Education

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Part I

Trends in Pre-College (K-12) Engineering Education (II)

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- T. Lewis** 843–852 Engineering Education in Schools

Challenges that attend attempts to introduce engineering education into schools are explored and claims by the technology education community as credible purveyors of this knowledge examined. The article contends that the primary challenge besetting the establishment of engineering knowledge in the schools is absence of a comprehensive knowledge base. This is complicated by the fact that the teachers are typically not engineers, and accordingly are handicapped. Just who should teach the content is also an area of tension. Technology education has made strong claims regarding the teaching of engineering design. Here the article argues that this tradition has an empirical and creative focus that makes its claims credible. It concludes that ultimately all claimants to the subject, under the guidance of engineers, must collaborate around provision of the knowledge base, as well as instruction.

Keywords: schools; knowledge base; pre-university education; engineering pathway

- E. A. DeBartolo and M. Bailey** 853–860 Making Engineering Appealing for Girls: Programmes for Grades 6–12

The Rochester Institute of Technology's Women Engineering programme (WE@RIT) has developed a continuous series of outreach programmes to stimulate an interest in engineering as a career for girls in grades 6–12. Events include: Park and Ride, a 6th and 7th grade amusement park design programme; Expanding Your Horizons, an 8–10th grade engineering and science conference; the SWE Overnight and Shadow Programme, an introduction to Engineering at RIT for 11th grade women; Colleges and Careers, a summer recruiting workshop for 12th graders; and WE@RIT Weekend, a three-day experience for young women who have been accepted to RIT, but who have not yet decided whether or not to enroll. In addition, WE@RIT has developed and piloted several travelling engineering activity kits (TEAK) to bring engineering experiences to students unable to come to campus for an organized workshop. Although these programmes are still new and limited, long-term survey data have been collected; preliminary results show that the activities do help girls to take a broader view of what engineers do and portray RIT as a friendlier engineering campus.

Keywords: pre-engineering programmes; diversity; women in engineering; K–12; outreach; retention

- W. Church, B. Gravel and C. Rogers** 861–867 Teaching Parabolic Motion with Stop-Action Animations

Historically, teachers determine the mental models that students have of various concepts by asking them to write. In physics, teachers will use lab reports and class tests, with variable success, to encourage the students to critically examine their mental models and to write about them. With the increasing accessibility of movie making, we have found a new avenue for students to examine and to report their models, and this new avenue is often more intriguing to the student. The goal of a lab report is for the students to tell a story, and through that story, critically examine their understanding of the subject. Having a student report on the outcome of an experiment, however, does not always lead to a change in student understanding. And, in extreme cases, a report can lead to the students changing their memory of the experiment to fit their incorrect mental model. Therefore, many teachers have the students predict first and then compare their predictions with their results. In the movie-making program, we try to take this a step further. We can use the movie environment to encourage students to build a simulation of their experiment and test their model against experimental data. As in engineering, this process relies upon strong fundamental math and science knowledge. In the classroom, generating animations serves as a way to strengthen conceptual understanding. Using the animation design process, we have found students (and teachers) to be far more interested in the outcome of their work. This paper shows some of the results of this technique by looking at how high school students have learned about parabolic motion in a physics class. In particular, we will highlight the work of select students to show what they were able to do through making a movie.

Keywords: animation; engineering design process; physics; mental representation; mental models

- R. Hixon** 868–873 Teaching Software Engineering Principles Using Robolab and Lego Mindstorms

Engineering can be made real and enjoyable to young children while providing opportunities to teach engineering applications. A robotics camp was developed to teach general programming concepts to elementary and middle school children using Lego Mindstorms kits. The camp could easily be expanded to teach students in high school. In recent years, engineering has been taught in very few K–12 schools causing a problem in recruiting students for engineering at the college level. Ideas for promoting engineering include training teachers at the K–12 grades to teach engineering and involving parents at this age level to follow through to graduation with training [1]. The curriculum developed for the weeklong camp could be used by fourth through eighth grade teachers to acquaint students with

programming skills needed for computer engineering in high school and college. Since children of all ages enjoy playing with robots, the Team Challenge (Lego Mindstorms) kit developed by Lego Educational Division is an excellent teaching tool. Robolab, developed by Tufts University, can be used to teach computer engineering principles to fairly young students. Students starting at age ten, eleven or beyond can start to understand and enjoy software development using these kits. A weeklong camp using Team Challenge kits with Robolab was developed to teach children of these ages programming concepts that could be used in all programme design. An advantage of Robolab for this age group is the icon-based language, making it easier to understand than a written programming language.

Keywords: middle School education; Robolab; Lego Mindstorms

L. G. Richards, A. K. Hallock and C. G. Schnittka 874–883 Getting Them Early: Teaching Engineering Design in Middle Schools

At the University of Virginia, we have undertaken a major project to design, implement, test and distribute Engineering Teaching Kits (ETKs). These kits introduce engineering concepts and methods into existing middle school science and maths classes. Students learn about essential engineering functions such as how to design, build, analyse, test and redesign. ETKs promote awareness of the nature of engineering and stimulate excitement about its practice. Twenty-two ETKs have been field tested in local middle schools.

Keywords: K–12 engineering education; pre-college outreach; engineering design; engineering teaching kits; middle school science and maths

D. Baker, S. Yasar-Purzer, S. R. Kurpius S. Krause and C. Roberts 884–893 Infusing Design, Engineering and Technology into K–12 Teachers' Practice

A graduate course for teachers on Design, Engineering and Technology (DET) was designed to infuse DET concepts and activities into the teachers' own practice. Three teachers who took the course were studied in depth to document the impact of the course in helping them implement DET in their lessons. Data for this study consisted of open-ended pre and post surveys, seven reflection papers, a DET unit plan written by the participants and participant interviews. An emergent-theme qualitative data analysis revealed meaningful patterns of change as the data were organized, categorized, reduced, coordinated and verified. Four key themes were revealed through this process: Reflections on Practice; Changes in Practice; Intentions to Change Practice; Changes in Knowledge. The case studies showed the following changes that occurred in participants' own teaching activities. Alice, an elementary school teacher, changed her practice by using DET concepts through having her children design a desert tortoise habitat. Denise, who taught at a science centre, changed her practice by shifting from crafts-based to design-based activities. Dana, a high school honours chemistry teacher, changed her practice by having her students design and build a lab instrument (calorimeter) and design associated lab activities. The teachers reported that the course's sharing and interactive activities promoted their ability to change. These activities included: reading and discussing research on classroom applications of DET; discussing possible changes in their own practice; sharing successes and failures in developing and trying their own lessons; receiving feedback to refine their lessons over the semester. Overall, the course and its activities were a catalyst in transforming the teachers into a community of learners who supported one another as they infused DET into their practice.

Keywords: engineering design in K–12 practice; emergent-theme data analysis; community of learners

J. S. Burmeister, T. Foutz and S. Thompson 894–901 Sophomore Engineering Design: Back to the Future

Design is a critical component of any engineering curriculum. It is possible to integrate a sophomore engineering design course focused on the theory of design and its application with the curriculum found in an elementary (K–5) school. The primary objective was to design science demonstrations for local elementary schools as part of a sophomore design course at The University of Georgia. This joint venture proves to be valuable for both sophomore engineers and elementary science students.

Keywords: Engineering; design; sophomore engineering design; elementary school science projects; K–5 design; customers; constraints

S. Sobhan, N. Yakubov, V. Kapila M. Iskander and N. Kriftcher 902–909 Modern Sensing and Computerized Data Acquisition Technology in High School Physics Labs

Under a National Science Foundation (NSF) funded GK–12 Fellows project, a solution to invigorate high school students' interest in science, technology, engineering and mathematics (STEM) careers is being examined and implemented. For an overview of our strategy and results from the first year of the project see below.

Keywords: data acquisition; GK–12 Fellow; high school; lab experiment; outreach; physics; sensor; STEM

J. K. Lumpf, K. D. Bradley and R. T. Haines 910–915 Kentucky Electronics Education Project (KEEP): Putting Professional Development into Practice

The Kentucky Electronics Education Project (KEEP) uses microelectronics to develop standards-based maths, science and technology curricula. KEEP provides training and support for teachers to build electronic circuits in their classrooms. This study examines over 200 student evaluations collected during Spring 2003 and 2004 of KEEP implementations. Rasch analysis and descriptive statistics indicate high student satisfaction with KEEP activities and a desire to learn more about the themes of the project. The goal of the project is to develop a K–16 learning environment, where students, teachers, university faculty and higher education students are engaged in curriculum development and enhancement.

Keywords: Professional development; pre-engineering; circuit building; Rasch analysis; grades 9–12; integrated curriculum

Part II

Contributions in: Engineering Education Research, Gender Issues, Nanotechnology, University-Industry Cooperation, Accreditation, Control Engineering, Engineering Graphics, Electronics, Civil Engineering and Industrial Engineering

M. Ogot and G. Okudan 916–928 A Student-centred Approach to Improving Course Quality Using Quality Function Deployment

This paper presents the development and an application of a quality function deployment (QFD)-based methodology that will lead to increased student satisfaction with their educational experience in a redesigned course. The key elements of the approach are to obtain and categorize attributes that would constitute a good course, and an effective instructor from the students' point of view. Mapping these attributes to established pedagogies found in the literature, coupled with continuous assessment and refinement ensures that there is no mismatch between student and faculty expectations. The approach was successfully implemented in a first-year engineering design course that had previously undergone a major revision in content and delivery, which resulted in student dissatisfaction and very poor student evaluations at semester's end. Maintaining the new content, the QFD-based approach helped significantly increase student satisfaction with the course.

Keywords: QFD; engineering design

The current work environment requires engineers to be global citizens, as well as aspirational, ethical leaders. To foster this new generation of engineering talent, modern curricula must advance strong analytical skills, creativity, professionalism, and leadership. However, a new curriculum with poor student retention cannot be deemed successful. The key components of a successful curriculum appear to be well-designed academic programs, dedicated faculty and strong support services. At the Ira A. Fulton School of Engineering (FSE), we believe that we possess these key components and yet approximately 65% of enrolled students leave our School. There is widespread speculation about the reasons for leaving, including financial need and lack of academic preparedness. To address these national and local attrition-related phenomena, a survey was designed to obtain clear quantitative information about why students leave FSE. During the fall 2005, students, who over several years transferred from engineering to a different school within ASU, were asked to complete an online survey. The hope was that information gained could be a basis for decision making and assessing proposed improvements for increasing retention. The aim of the study was to discover factors with the greatest bearing upon the decision to leave engineering. This research elicited student attitudes concerning educational experiences in their new major contrasted to their engineering experiences. The key questions investigated in this research are: What factors contribute to the decision to leave FSE? How does the student's experience in their new major compare to their experience in engineering? What factors in our programs promote loss of student talent?

Keywords: Advising, assessment, culture, curriculum, education, engineering, faculty, persistence, and retention

An educational module has been developed and implemented at the ETSEQ (University Rovira i Virgili, Spain) to facilitate the transition of first-year ChE students into a comprehensive project-based learning environment. All first-year students participate in the first-year integrated design project with fourth-year ChE students acting as project managers for first-year project teams. The eight-hour module is taught during the first two weeks of the first term and is structured to take into account the factors needed for students to understand and commit themselves to change. The first-year students' evaluation shows that the module helps them: (1) to identify what they need to accomplish to gain future employment as chemical engineers; (2) to understand what an integrated design project consists of and what the benefits of teamwork are, and (3) to realise that the integrated project and the related teamwork are great opportunities to acquire competencies that are essential in today's workplace.

Keywords: change management; first-year students; project-based learning

Development of the technical and social skills of students using project orientated and problem-based learning (POPBL) in teams is well documented. In this article the authors are concerned with their experience of integrating individual activities in a team-orientated POPBL setting. The question raised and discussed is: 'can students gain more professional and personal skills and provide better solutions through integrating an individual activity in team-based project work'? Based upon a two year pilot experience, the authors describe the rationale for individuality in POPBL; the way individual activity was structured and performed; and which experiences have been gained. The conclusion is that the introduction of individual activities has clear advantages for the learning motivation of individual students, the quality of group work and for the development of professional and personal competences.

Keywords: problem based learning; project based learning; teams

This paper examines the 20-year career paths of three women engineering graduates who took part in a larger quantitative/qualitative research study on the career mobility of engineers in the province of Manitoba, Canada. The results of in-depth interviews reveal that women graduates of the 1980s, while subject to discriminatory attitudes and practices at the beginning of their careers, have also been beneficiaries of societal, organizational and engineering-related improvements towards gender equity. Implications are drawn on the importance of mentoring strategies to women's career success in the field.

Keywords: women; sociology; mentorship

A new sophomore-level nanotechnology course was developed and co-taught from seven disciplines: biology, chemistry, physics, materials science, electrical, mechanical engineering and ethics. The goal of the course was to provide a descriptive view of nanotechnology for biological applications. Several faculty members co-taught the course, and a course coordinator assisted in integrating the course content. Our new course was taught both in the spring 2004 and spring 2005. Our experiences learned from the 2004 course were transferred to the 2005 course. Our classes consisted of biology and engineering students. Because the backgrounds of the biology and engineering students were entirely different, the students were grouped into interdisciplinary teams on their class project and homework assignments. Teambuilding fostered better communication and improved learning.

Keywords: nanotechnology; teaching strategies; co-teaching

This paper describes a framework for synergistic collaboration between National Instruments (ASEAN) and Monash University Malaysia (MUM). This work involves the development of a remote-access web-based engineering laboratory. This paper first stresses the importance and need for collaborative partnership between the industry and university for the enhancement of engineering education. The main goals are to enhance the engineering curriculum and offer a complementary learning experience for students through remote web-based experimentation. Then, it states and discusses the four main enabling factors for developing durable, sustainable alliances formed by this industry-university collaboration. Lastly, this paper reflects the management of this successful collaborative experience and stresses the importance of the proposed critical factors.

Keywords: synergistic collaboration; enhancement; engineering education; remote-access; web-based experimentation

For more than two decades, the Hong Kong Institution of Engineers has been administering its Engineering Graduate Training Scheme 'A' (Civil) for the purpose of transforming graduates of accredited civil engineering degree programmes to become professional civil engineers through supervised or controlled training. A study on whether the training scheme is fulfilling this purpose was performed. This included the identification of the range of qualities that a professional civil engineer should possess and the evaluation of whether the training scheme can ensure trainees acquire all these qualities to an acceptable level.

Keywords: training scheme; training objectives; knowledge; experiences; competencies; qualities; continuing professional development (CPD); engineering supervisor; professional assessment; qualification; standard

P. Company, M. Gomez-Fabra, M. J. Agost and M. Vergara 990–999 Assessment Strategy to Engage Students in Constraining Parametric CAD Drawings

The appearance of CAD applications with parametric capabilities has not changed some obsolete academic habits based on drawing as if a ruler and compass were still the tools used for this purpose. In this work, it is argued that this is not reasonable in terms of training strategies or in terms of efficiency. To support this statement, a new method of evaluation that measures and compares the efficiency of different geometrical construction approaches is presented. The use of this metric as a teaching strategy is illustrated through an experimental study applied in the classroom.

Keywords: computer-aided design; geometrical constructions; geometric loci; geometric constraints

D. Ibrahim 1000–1010 Low-cost Microcontroller-based Hardware for Introducing Digital Filter Fundamentals to Students

Digital filters are currently created using high-performance DSP chips. Although these chips have many advantages in commercial and industrial applications, they usually oversimplify and hide away the basic concepts for the realization of digital signal processing techniques. This paper describes the design of a digital filter using a low-cost microcontroller as the processing element. The main feature of the system is that it aims to teach students the basic hardware and software implementation of digital filters. Both FIR and IIR type filters can easily be implemented with the system; the developed platform will be used at the Near East University together with DSP chips to teach the practical realization of digital filters to undergraduate students.

Keywords: Digital filter; FIR filter; IIR filter; DSP; microcontroller, MATLAB

J. M. Díaz, S. Dormido and J. Aranda 1011–1023 An Interactive Software Tool for Learning Robust Control Design Using Quantitative Feedback Theory Methodology

We present the main features of Quantitative Feedback Theory Interactive Tool (QFTIT) a new interactive software tool for robust control design using the Quantitative Feedback Theory (QFT) methodology. The main advantages of QFTIT compared to other programs are its ease of use and its interactive nature. All that the end-user has to do is to place the mouse pointer over the different items which the tool displays on the screen. Any actions carried out on the screen are immediately reflected in all the graphs generated and displayed by the tool. This allows users to perceive the effects of their actions during the design of the controller. QFTIT has been designed bearing in mind the needs of beginners who want to learn the QFT methodology as well as the needs of advanced users. The tool is freely available in the form of an executable file for Windows or Mac-based platforms. In this paper, a robust control problem is solved with QFTIT in order to demonstrate the tool.

Keywords: quantitative feedback theory (QFT); robust control; control systems computer-aided design (CSCAD); educational software

C. Savander-Ranne, U. Häggblom-Ahnger and S. Kolari 1024–1037 Educating Pulp and Paper Engineers for the Global Forest Industry

As the business of the Finnish forest industry companies expands increasingly over the borders of our country, a newly graduated engineer must possess professional skills, know the international business and marketing, understand multicultural business life situations and speak English fluently. In this paper the authors describe an International Pulp and Paper Technology (IPPT) specialization option at Tampere Polytechnic University of Applied Sciences and pedagogical means that have been adopted as a response to the challenges that globalisation causes to engineering education in pulp and paper technology. The main idea of the IPPT specialization option is to achieve content and language integrated learning (CLIL). In order to achieve this, versatile pedagogical means have been adopted such as pre-lecture assignments, cooperative learning sessions, miniseminars and seminars, negotiation simulations and writing learning journals. The first implementation of a renewed pulp and paper specialization option is described as well as the impact of the changes on student learning. The pros and cons of adapting quite a few different teaching methods are also discussed. This research is a case study and can be classified as action research with evaluative features.

Keywords: CLIL; content and language integrated learning; developing teaching methods; student-centred teaching methods

S. O. Cheung, P. S. P. Wong, R. K. F. Kam and P. P. K. Wong 1038–1049 A User-oriented Web-based Multimedia Programme for Measuring Building Services Engineering Works

It has been noted that, with the advance in multimedia and information technology, many traditional classroom-based teaching activities have migrated on-line. However, without a proper design framework, a lot of these programmes are just on-line information disseminators. This paper describes a web-based self-learning measurement of building services engineering work programme (MBS) that features the characteristics of three well-established web-based design paradigms: objectivism, cognitivism and constructivism. The programme covers the measurement principles of four of the most commonly installed building services engineering works: electrical installation; heating, ventilation and air conditioning (HVAC); fire services; and plumbing and drainage installations. In addition to the basic contents or measurement rules, the programme is also equipped with a user guide, worked examples, a discussion forum and on-line self-assessments. An evaluation of the effectiveness of the MBS as a learning platform is also provided.

Keywords: web-based; multimedia; building services engineering