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Engineering Education Research and Policy
- H.-J. Witt, J. R. Alabart, F. Giralt, J. Herrero, L. Vernis and M. Medir** 218–235 A Competency-Based Educational Model in a Chemical Engineering School
An educational model has been designed and implemented at the School of Chemical Engineering (ETSEQ) at Tarragona, Spain, to enable ChE students to acquire and integrate technical and scientific knowledge through the simultaneous and gradual development of competencies encompassing social and management skills. This model is based on the large-scale deployment of a project-based cooperative learning approach throughout the ChE curriculum. This extensive deployment can only be effective if it is supported by experts in change management and the systematic development of student teams that, in turn, requires that individual students develop key social and management skills. To this end, a partnership between the ETSEQ and Dow Chemical Ibérica was established in 1997. The expertise of Dow Chemical in team development and change management methodologies, gained from nearly a decade of implementation work, has complemented the practice of the ETSEQ with experiential learning methodologies. A set of external training interventions has been designed to support the development of competencies by students. In the new educational system student teams grow from leader-directed teams in the first semester of the first academic year to self-directed or empowered teams in the fifth year of the curriculum. In this empowerment journey, fourth-year students play a key role as they act as facilitative leaders of first-year and second-year project teams, adjusting their facilitative leadership role according to the team development stage. The core of the competency-based educational model is client orientation. The need to satisfy clients and to adapt to their changing needs triggers the development of competencies related to the transformation of the individual students (versatility, entrepreneurship and innovation, systemic thinking, etc.), of the organization (facilitative leadership, teamwork and cooperation), and of the institution (organizational development and performance, and organizational leadership). Preliminary results show that student attendance has increased, that drop out has decreased, that more professors act as facilitators in the classroom, and that active-oriented and student-centered educational methodologies are increasingly applied. In addition, the number of internships and first-job hirings at Dow has increased by nearly tenfold and threefold, respectively, since the first students educated under the new system graduated.
- J. F. Vivas and V. Allada** 236–246 Enhancing Engineering Education Using Thematic Case-Based Learning
This paper describes a learning architecture for developing a series of case-based studies that are linked by a common thematic basis. The proposed architecture takes into account 'four forces' that influence the development of the thematic cases: namely, Bloom's learning levels, industry cases to add realism to the engineering curriculum, the plug and learn approach, and incorporation of business and management issues in the context of engineering problem-solving. We developed a set of three industry case studies using the lean manufacturing/continuous improvement theme and cover various topics such as total productive maintenance (TPM), reduction of energy waste, process mapping, quality improvement, and various business and managerial issues. This series of cases is intended to immerse students in situations that they could expect to encounter while working in an industrial setting by emphasizing the usage of engineering and business tools and methodologies in the context of a real-life project. We believe that our approach, of developing theme-oriented case studies as opposed to isolated case studies, will help the students to internalize learning. Students are often taught various tools and techniques, but they may not necessarily see if and how these complement each other. We believe that presenting the tools and techniques around a thematic basis will help the students to understand 'how, when, and which' tools and techniques need to be applied in a given context. We also conducted preliminary experiments to ascertain the value of the case studies to the students.
- J. T. McLeskey, Jr., J. E. Speich, J. S. Richardson and M. Gad-el-Hak** 247–256 Evaluation of an Experiential Engineering Library
The VCU Mechanical Engineering Department has developed and tested an NSF-sponsored 'Experiential Engineering Library' that provides an easily accessible environment for hands-on learning experiences beyond the traditional ME curriculum. The library fosters critical thinking by encouraging students to apply fundamental mechanical engineering principles to emerging interdisciplinary research in fields including microelectromechanical systems (MEMS), bioengineering, and nanotechnology. Experiments come from state-of-the-art faculty research as well as other sources and are assigned as a complement to, or in lieu of, paper and pencil homework, or utilized independently by students seeking to improve their understanding. The library concept has been described in detail in a previous IJEE paper. The present article describes the implementation and impact of the four library learning modules into the four courses during the year-long pilot program. The library has been found to be effective in improving student understanding as well as motivation.
Keywords: Guided Discovery; Hands-On Learning; Modules; Constructivist Learning Theory
- S. Haag, E. Guilbeau and W. Goble** 257–263 Assessing Engineering Internship Efficacy: Industry's Perception of Student Performance
Ira A Fulton School of Engineering administrators and faculty have integrated curricular materials and strategies to ensure that students possess the competencies that are embedded in the Accreditation Board for Engineering and Technology (ABET) criteria. One measure to assess student performance is to gather feedback from industry managers who employ students as interns while they are still enrolled in school. The current study examined internship program efficacy in the Ira A Fulton School of Engineering. Program success was determined by the following three criteria: 1) student performance outcomes based on ABET criteria, 2) number of student participants and industry partners, and 3) industry-university collaboration. A primary objective of this study was to develop an assessment instrument and process that would capture alignment between ABET criteria and student performance in internships. This paper will outline critical inherent variables that contribute to internship program impact and will describe methods to enable assessment alignment between program outcomes and accreditation criteria. Industry feedback reveals that both undergraduate and graduate students possess the majority of skills defined in the EC2000 a–k competencies. Significant differences between undergraduate and graduate students were not evident. This is an important finding particularly in terms of accreditation criteria. Faculty who teach undergraduate higher-level courses may also teach graduate courses. Thus, it is likely that instructors who have been implementing methods to accomplish school objectives and outcomes in their undergraduate courses are also integrating those same strategies into their graduate courses. The formative assessment has determined program strengths and opportunities for improvement and thus will define further practices and processes to ensure future success.

The fostering of creative students has become a crucial issue in engineering education in recent decades. This paper examines staff members' perceptions of creativity in Taiwanese engineering students. Several studies have reported how teachers perceive the nature of creativity. However, the studies have produced varying results because the samples have been drawn from different educational groups, academic disciplines, and geographical areas. The present study investigated the characteristics of creativity as perceived by 175 academic staff members from two Taiwanese universities. The perceptions of creativity by university academic staff were found to be different from those of primary or secondary school teachers. Rather than emphasizing extrinsic characteristics, such as questioning and responding (as had been done by primary school teachers in previous studies), engineering academic staff members paid more attention to intrinsic characteristics, such as logical thinking. In all, 21 important characteristics of creativity are identified in this study, and these are categorized into five dimensions.

Keywords: creative characteristics; perception of creativity; creativity survey

S. Shakerin

273–278 The Art of Estimation

The ability to perform estimation is an asset, for example, when dealing with problems with limited or unavailable data. Engineering students, in general, are inadequately prepared to perform rough estimation. A possible reason for this shortcoming is that the emphasis in engineering curricula is on detailed analysis and not enough attention is given to developing students' estimation skills. This paper outlines the importance of estimation and lists attributes that are necessary to carry out reasonable estimation. Furthermore, it provides a list of activities and exercises, appropriate for use in the lower division courses, to engage students in estimation scenarios and to launch them on a path to developing this skill.

W. H. Fok and A. H. P. Chow

279–289 The Engineering Graduate Training Scheme 'A' (Civil) of the Hong Kong Institution of Engineers—a comparison with civil engineering graduate training schemes

An engineering graduate training scheme refers to a scheme for transforming graduates of engineering degree programmes to become professional engineers through supervised or controlled on-the-job training. The background, content and administration of the established Engineering Graduate Training Scheme 'A' (Civil) of the Hong Kong Institution of Engineers were detailed and compared with other similar civil engineering graduate training schemes. An evaluation on its position amongst these comparable training schemes was also performed.

Keywords: training objectives; practical experience; continuing professional development (CPD); training log book; professional experience; professional assessment; accredited degree; training certificate; engineering supervisor; training tutor; mentor

Gender Studies

S. Ingram

290–299 Women Engineering Graduates from the 1970s, 80s and 90s: Constraints and Possibilities of a Non-Traditional Career Path

This paper is a retrospective account of three women graduates from a Canadian school of engineering whose experiences span a 25 year period from the 1970s, where women's enrolment was sporadically few, to the late 1990s, where it achieved close to 25%—the largest enrolment seen to date. In-depth interviews were conducted with these women focusing on their university and work experiences and the barriers they have encountered. Their profiles reveal that while women's structural representation in engineering improved significantly during this time span, cultural practices and attitudes towards them have been more resistant to change. Key areas connected to career success are touched on, including mentorship, networking and the importance of gaining acceptance into male engineering circles. The author has kept the precise identity of the institution and its locale confidential due to participants' concerns about maintaining anonymity and some events and practices, which although representative of many universities at various points in time, could be seen as damaging.

Keywords: women; industrial experience; sociology

Information Technology

H. Yang and R. Chein

300–307 Communication Component Fabrication Educational Program for Information Technology

Since the propagation of global communications, information technology (IT) plays a very important role in improving quality of life. Educational institutions have the responsibility to educate students with knowledge in this field. A fundamental IT educational program is currently conducted in the College of Engineering, National Chung Hsing University, Taiwan. This IT program is based on three main IT technology subjects: system, design and fabrication. Five subprograms are designed based on the interrelationships between these three subjects. In this paper, we present the teaching goal, curriculum design and teaching outcome of one of these subprograms aiming for enhancing the students' ability in communication component fabrication. We focus particularly on the students' ability in system integration including theory, microfabrication, packaging and testing. Course teaching is accompanied with hands-on experiments performed in the supported laboratories. From the student projects, it was found that this subprogram successfully achieved the educational goal. The students were able to integrate the knowledge in class to create innovative communication systems and microfabrication processes.

Keywords: information technology (IT); communication component fabrication; and microfabrication.

Electrical and Electronic Engineering

P. Lundgren, K. O. Jeppsen and A. Ingerman

308–314 Lab on the Web—Looking at Different Ways of Experiencing Electronic Experiments

Students who perform a laboratory exercise via the Internet display decisive differences in how they approach this resource: either as just a way to gather data, as illustrations of theory or as a tool for reflection and testing of hypotheses. From more than 200 written student log books, student interviews and video recorded lab sessions we conclude that the students' approaches to measurements conducted through the Internet are very similar to that of measurements conducted with the students present in local classroom labs. Possible measures to support students in adopting a desirable approach to measurements are discussed.

J.-H. Su, C.-L. Chien, J.-J. Chen and C.-M. Wang

315–322 Simulink Behavior Models for DC–DC Switching Converter Circuits using PWM Control ICs

Simulink behavior models of DC–DC switching converter circuits using pulse-width modulation (PWM) control ICs are devised in this paper. Although some assumptions are made to simplify the Simulink behavior models, the likeness between the simulation and experimental results for both transient and steady-state responses shows that these behavior models capture almost all the important characteristics of the DC–DC switching converter circuits. Therefore, these behavior models can be very good teaching aids for students to learn the differences between ideal circuits and practical implementations. With these Simulink behavior models, students can also validate quickly whether or not their designs of feedback controllers for DC–DC switching converter circuits implemented with PWM control ICs meet the prescribed performance requirements.

The well known parallel-plates transmission line is solved efficiently by the moment method, where the entire domain expansion functions contain the edge behavior of the fields. It is shown that two expansion functions are enough for an excellent convergence of the solution, in agreement with the analytical conformal mapping solution. Our moment method solution is also compared to other moment method solutions.

Industrial Engineering

The pivotal idea central to engineering education is the cultivation of a motivation-based environment. There is little doubt that students learn better, particularly with regard to 'deep learning' if they are allowed to focus on areas of a curriculum in which they are strongly motivated. On the other hand, engineering education can also be regarded as an integrated study for students, which foster the cultivation of basic skills and the talent to follow well-defined patterns of procedures in order to solve problems. This paper presents the design and implementation of an educational simulation which mimics a microworld of business activities. The objective of such educational simulation is to present an integrated environment for students to undergo a motivation-based learning experience based on an integrated study methodology. The design and implementation of the educational simulation is intended to motivate students to accept personal responsibility for behavior in a simulated environment by recognizing and taking pride with a sense of self achievement.

Keywords: integrated study methodology; motivation-based learning; educational simulator; logistics workflow inventory management.

Manufacturing Engineering

This work describes the introduction of microscale manufacturing education into the mechanical engineering curriculum at the Purdue University. Lectures and laboratories on microscale manufacturing are integrated into an undergraduate technical elective course, Principles and Practices of Manufacturing Processes. Three one-hour lectures introduce fundamental microfabrication processes with a focus on soft lithography. Two microfabrication laboratories have been designed, developed, and implemented using a newly developed pilot facility within Purdue's Multiscale Manufacturing Center (MMC). Through the laboratories, students gain hands-on microfabrication experience and achieve devices with features as small as 10 μm . We expect this work will serve as a model to establish similar manufacturing educational laboratories at other institutions.

Engineering Design

Many engineering courses are characterized by having to produce one-off, technically complex artifacts to demonstrate that learning has been achieved. This paper introduces 'Rapid Prototype as Design' as an effective methodology to help students produce effective results in their engineering projects. This paper presents a case study on the GlucoFridge, a pocket-sized, battery powered, insulin refrigerator which was a technologically complex project involving a variety of technologies. The product was developed in three months through the tight integrated use of virtual and physical rapid prototyping technologies that allowed for an extremely fast reiterative design approach and a short development time.

Engineering Graphics

Dimensioning is one of the most important stages in design development. It is traditionally learned through the sketches or drawings of parts to which the student adds their dimensional values. However, there are no computer teaching applications which are specifically oriented towards teaching the student how to dimension and showing what alternatives exist for such dimensioning. A methodology has been developed based on a computer application which in turn is based on variational geometry, which will allow students to design a sketch and obtain the different alternative dimensions, in line with ISO 129. Creating sketches through conceptual design implies the use of constraints. When developing conceptual design-based CAD programs, two independent modules must be created: on the one hand, the sketcher module, which must define the model's geometrical constraints and interpret the user's intention through a system of rules. On the other hand, the calculation module which must solve the final geometry and eventually dimension the mechanical part. The proposed approach establishes the complete geometry and constraints of a sketch and relates it with the complete dimensioning of the sketch. The developed methodology gives as a result a complete and consistent dimensioning of the sketch following the rules established by a standard like ISO. The methodology establishes the most suitable dimensioning but, if the student wants to substitute any dimension for another, the algorithm automatically reconfigures the complete dimensioning and proposes another different complete one.

Keywords: Dimensioning; technical drawing teaching; ISO 129; automatic sketching

Thermal Engineering

In this paper we present infrared thermography as a technique to aid the process of teaching-learning in subjects related with heat transfer. The main aim pursued is to make it easier for students to learn and understand the phenomena involved in heat transfer modes in a fast, intuitive way by using infrared images. To achieve this objective we have developed a series of exercises for use in practice sessions. Here, we describe some of the practical exercises concerning the different heat transfer mechanisms: conduction, convection and radiation, and share the results obtained from our experience gained over two academic years.

Mechanics

Classroom implementation of a new approach to teaching statics is presented here. This new approach, which was explained in a companion paper [1], is based on the need to address the important concepts of statics first in isolation, and the recognition that students do not perceive the forces between rigid, inanimate objects. Hence, statics instruction was revised to focus on individual concepts in the context of situations in which all the forces are readily perceived. In this paper we demonstrate an implementation of this approach that draws upon widely accepted classroom techniques to promote active learning: peer-to-peer collaboration, integration of assessment and feedback into classroom activities, and the use of concrete physical manipulatives. With the development of learning modules, which feature objects to manipulate or examine, PowerPoint presentations and concept questions, the authors have transformed this instructional approach into practical classroom tools. The details of classroom implementation, extensive excerpts from the modules, and an assessment of the efficacy of this approach are presented.

The mechanical properties of a vertically dropped ball, represented by an equivalent mass-spring-damper model, are shown to be related to impact parameters. In particular, the paper develops relationships connecting the mass, stiffness and damping of a linear ball model to the coefficient of restitution and the contact time of the ball with the surface during one bounce. The paper also shows that the ball model parameters are functions of quantities readily determined in an experiment: (i) the height from which the ball is dropped from rest, (ii) the number of bounces, and (iii) the time elapsing between dropping the ball and the ball coming to rest. For a ball with significant bounce, approximate expressions are derived for the model parameters as well as for the natural frequency and damping ratio. Results from numerical and experimental studies of a bouncing ping-pong ball are presented.

Keywords: mechanics; dynamics; mass-spring damper model; coefficient of restitution

A novel method to solve planar vector equations in two unknowns is outlined and developed and its application is illustrated in the context of kinematic analysis. The problem is classified in terms of all four possibilities concerning the combinations of unknown pairs of vector magnitudes and directions, which may arise in the course of formulation. Through extensive use of 1×2 and 2×1 matrix multiplication and the 2×2 planar, proper orthogonal operator, it is believed that this method offers advantages of simplicity and computational efficiency as well as robustness, compared to conventional approaches.

Keywords: Planar mechanism; vector equation.

Software engineering

Proper design analysis is indispensable to assure quality and reduce emergent costs due to faulty software. Teaching proper design verification skills early during the pedagogical development of a software engineer is crucial, as such analysis is the only tractable way of resolving software problems early when they are easy to fix. The premise of the presented strategy is based on the observation that a fundamental component of any engineering discipline is the use of formal and sound techniques that facilitate analysis of produced artifacts. Yet, fundamental roadblocks exist in bringing the state of the art in formal design analysis to the undergraduate software engineering classroom due to the steep learning curve and quagmire of theoretical details involved in formal methods. This paper suggests a strategy and tool support to improve the attainment of software design verification skills. We illustrate how selective and pragmatic application of model-based verification methods can be used in software design education via tools that aim to bridge the gap between students' semi-formal design worldview and the formalism underlying formal methods.