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This contribution reviews the requirements for a successful professional career and the scope of materials engineering as a specific area of professional competence. Basic concepts associated with communication and performance in the engineering workplace are summarised. The selection of core courses for materials engineers is discussed and the role of case histories in developing engineering insight is emphasized. The extent to which technological forecasting and risk assessment can be usefully included in the course curricula is also assessed and some of the dilemmas associated with the undergraduate teaching of professional ethics are noted.

Keywords: Materials; knowledge acquisition; career; case histories; catastrophic failure.

- R. N. Savage 917–924 The Role of Design in Materials Science and Engineering

Learning to apply the design process can be the key to understanding the blending of Materials Science with Engineering. Design is a method that involves both inquiry and innovation but it is also constrained by such practical factors as time-to-market and cost-effectiveness. Engineering students must learn to recognize the similarities and differences between the scientific and design methods. Both can be looked at as systems for solving problems; however, the input for the scientific method is a theory with the output being increased knowledge, while the input for the design method is an application with the output being a device or process. Introducing design through project-based learning activities will enable students to see how the fundamental concepts of science and math can be applied to solve complex engineering problems. It is imperative that students be exposed to the design process throughout their undergraduate education and this article will recommend methodologies for accomplishing this task.

Keywords: design method; systems engineering; project-based learning; critical thinking; teaming.

- B. J. Diak 925–936 Strength By Chocolate

We have developed an open-ended 10-week design project called Strength by Chocolate. The intent of this project is to expose first-year undergraduate engineering students to the central paradigm of Materials Science and Engineering (MSE). The project allows students unfamiliar with materials concepts to wholly design, fabricate, predict and test the mechanical properties of a reinforced chocolate composite. This paper describes the students' efforts to strengthen chocolate, illustrates some of the classic materials processing-structure-property behaviours observed in the composites, and discusses the benefits of using the MSE paradigm to teach materials.

'Strength is the capacity to break a chocolate bar into four pieces with your bare hands—and then eat just one of the pieces.'—Judith Viorst

Keywords: chocolate; food-based composites; materials design; mechanical testing; phase transformations.

- J. Stolk and R. Martello 937–950 Pedagogical Fusion: Integration, Student Direction, and Project-Based Learning in a Materials Science–History of Technology Course Block

Imagine a course block in which students discuss the cultural implications of 17th century iron working in North America in one hour, and design experiments to examine connections between composition and strength in modern steel padlocks immediately afterwards. In the Paul Revere: Tough as Nails course block, students don't just study materials science and history of technology topics, they experience them. Through a series of readings, discussions, and self-designed projects, students explore materials science concepts alongside the social, cultural and environmental factors that shaped technological and scientific history. Although the course includes many formal in-class activities, approximately half of all class sessions are flexible, allowing students to engage in individualized learning approaches. The projects are loosely framed, enabling students to develop key competencies while investigating topics of personal interest and controlling project focus and direction. In this paper, we discuss the processes and motivating factors that led to the initial design and continued development of the Paul Revere: Tough as Nails course block. We describe the pedagogical and practical benefits of the course, and we elucidate the important role the course plays in Olin's engineering curriculum.

Keywords: materials; technology history; project-based learning; assessment.

- S. Zhang 951–954 Teaching Electron Configuration the Musical Way

This paper describes a 'musical way' of teaching the electronic configuration of elements in the periodic table, thus taking the frustration and struggle out of the learning process and making it fun. In essence, the musical notes 'do, re, me, fa, so, la, ti' are denoted by seven digits 1, 2, 3, 4, 5, 6, 7 respectively, to represent the total number of electron energy shells. Sounding out the shell number in music immediately grasps the students' attention and they become instantly involved. The teaching is simple and the learning becomes fun. And hopefully, once learnt, the tune (and thus the electronic configuration) will be remembered for life—thanks to the magic of music.

Keywords: electronic configuration; periodic table; elements.

- C Baillie, P Goodhew and E. Skryabina 955–962 Threshold Concepts in Engineering Education—Exploring Potential Blocks in Student Understanding

In an attempt to discover what students find difficult or uninteresting in areas known to be troublesome in their materials engineering degree programmes, questions were posed to students in four universities across the UK as part of a larger study conducted by the UK Centre for Materials Education. We were keen to find out what it is that makes students like and dislike certain concepts in physics and mathematics which are compulsory parts of their degree programme. This paper considers this data in the light of the work by Meyer, et al., on threshold concepts and troublesome knowledge [1] together with our recent work on blocks and pathways to knowledge negotiation [2]. Ultimately we hope to uncover those pathways through threshold concepts allowing students access to a higher level learning potential.

Keywords: threshold concepts; troublesome knowledge; knowledge blockage; attitudes; complex numbers; barriers to learning.

R. M. Deacon, C. A. Prescott and W. Z. Misiolek 963–969 The ‘Lehigh Model’ for Introduction of Engineering to High-School Students at ASM Materials Camp

The Lehigh Valley ASM Materials Camp, held twice at Lehigh University, offered a new perspective on the way a materials camp for high-school students can be developed and presented. The distinguishing characteristic of the Lehigh Valley Chapter camp was that it was planned, developed, and presented by graduate student volunteers from Lehigh University. The focus of the camp was making materials science applicable to the high-school students by showing them how to recognize the role of materials science in applications they were already familiar with, such as sports, entertainment, and transportation.

Keywords: K-12; materials camp.

J. F. Mano 970–978 Classroom Methods for Demonstrating, Modelling and Analysing the Viscoelasticity of Solids

This work presents some topics related to the teaching and learning of viscoelasticity in solids at the undergraduate level. It is recommended that the molecular and mechanistic aspects assigned to the viscoelastic behaviour of materials should be focused on, besides all the mathematical formalism, experimental techniques and applications. Some suggestions are made on laboratory practices and demonstrations, where the use of dynamic mechanical analysis is exemplified. It is suggested that active and cooperative learning techniques could be implemented in this subject, in order to obtain higher results. Finally, some cases are presented on pedagogical experiments and demonstrations that could be executed in the classroom.

Keywords: viscoelasticity; glass transition; learning techniques; dynamic mechanical analysis; polymers.

S. Muryanto 979–985 Concept Mapping: An Interesting and Useful Learning Tool for Chemical Engineering Laboratories

This paper describes an ongoing study on the use of concept maps in an upper-division chemical engineering laboratory to enhance student learning. The Unit Operations Laboratory was chosen for the study since it is a comprehensive laboratory in which students are required to be familiar with various aspects of chemical engineering practice. The study was implemented in three stages. In the first stage the students were introduced to the idea and construction of concept maps. The second stage involved the construction of concept maps during a pre-lab session in which the students were orally tested about the exercise they were about to undertake. The last stage was the submission of the final reports in which the students were again required to hand in other concept maps. The students completed the lab practice in groups of three to four, and were asked to create both individual as well as collective concept maps. The present study produced three tentative findings. First, the first stage mainly produced simple concept maps that barely contained basic chemical engineering principles. These initial maps, however, developed and became more complicated as the students went on completing the lab practice and subsequently preparing the report. Secondly, it appears that each student wanted his/her contribution in the collective concept map construction to be acknowledged. Thus, the students were believed to be motivated. Thirdly, since the concept maps produced were collected and displayed in the lab for comparison with the subsequent lab sessions, the students seemed to get a feeling of continuity, something that is not normally noticeable in the traditional lab practice. These findings indicate that concept mapping has a positive effect on student learning. The paper ends with a discussion on the study with respect to its pedagogical values and applicability to other courses.

Keywords: concept mapping; chemical engineering; laboratories.

A. O. Kurt, C. Kubat and E. Öztemel 986–992 Web-Based Virtual Testing and Learning in Material Science and Engineering

This paper presents a conceptual model for the Web-based virtual testing and learning (WVTL) in applied sciences, especially in the area of materials science and engineering. WVTL is not an existing field but rather an idea, which could be easily handled for educational purposes and staff training as well as for new materials, products and prototypes testing. The paper reports exclusively on the use and services of simulations on the Web and the potential use of WVTL as well as the trends and opportunities in the area.

Keywords: Web-based testing; materials

J. Hashemi, N. Chandrashekar and E. E. Anderson 993–1002 Design and Development of an Interactive Web-based Environment for Measurement of Hardness in Metals: a Distance Learning Tool

An interactive Web-based experiment was designed as a preparation tool for students in the Materials and Mechanics Laboratory course at Texas Tech University. In the Web-based experiment, the students were given an introduction to the concept of hardness, what it means, how it is measured, and the calibration and utilization procedure using a Rockwell tester. In three semesters, three sections of the class were exposed to lectures but not to the virtual experiment and three sections (three groups) were exposed to both lectures and the virtual experience. Each group was given a pre-lab quiz to assess their understanding of the concepts and objectives of the experiment. The groups exposed to the virtual lab were also given a short quiz on the procedure of the experiment. The pre-lab quizzes were graded without prior knowledge of the students' section or group affiliation. Grades were compared between groups that were exposed to both the lecture and the virtual laboratory and those groups who were only exposed to the lecture. The average grade of the students in the lecture and virtual laboratory groups was approximately 20 % higher than that for the lecture alone group. This difference was statistically significant ($p < 0.05$) based on a t-test. The average grade on the knowledge of the procedure prior to actual experiment for the lecture and software groups was 75 on a 100 basis. Also, these students showed a great understanding of the hands-on procedure without significant input from the instructors. The lecture-only groups did not have a good idea of the procedural steps and required significant guidance from the instructor. Student evaluations of the software revealed that students were very enthusiastic about using the module as a pre-lab preparation tool but not as a replacement for the actual experiment. In this paper, the design of the software, important elements of the virtual lab and the evaluation results will be presented.

Keywords: Web; virtual lab; metallurgy; hardness test.

O. Baysal, M. Koklu and A. K. Noor 1003–1012 Design Optimization Module for a Hierarchical Research and Learning Environment

This paper describes a learning module on design optimization courses within a hierarchical research and learning network. In this environment a hierarchical learning network can be created to link diverse inter- and trans-disciplinary teams from a consortium of universities, industry, government agencies and the providers of learning technologies. It is an approach that builds on computer-based training, intelligent tutoring systems, interactive learning, collaborative-distributed learning, and learning networks. As an example of a learning module in this environment, the present design optimization module has been developed and described. This module allows learners of design optimization to get the course material at their own convenience via either the internet or packaged files. Consequently, it is expected that the learner's ability to understand design optimization and review its pertinent details will be enhanced significantly.

Keywords: asynchronous distance learning; advanced learning networks; sensitivity analysis; concept maps; shape optimization; computational fluid dynamics.

F. E. Sandnes, Yo-ping Huang and Hua-li Jian 1013–1022 Experiences of Teaching Engineering Students in Taiwan from a Western Perspective

Recently, there has been a growing interest in educational collaboration between the East and the West. More Western educators are traveling to the East to provide local students with an 'internationalization-at-home' experience. However, the literature on teaching Chinese engineering students from a Western perspective is sparse. Impressions, opinions and myths about how Asian students respond to western teaching styles are plentiful, and are often based on outdated facts or on observation of Asian students enrolled in Western universities. Chinese societies have changed drastically in recent decades. This paper addresses recent experiences of a Western teacher giving a course to Taiwanese engineering students. Advice is given on breaking the ice, gaining contact with students, activating students, overcoming obvious language barriers, and surviving a completely different education model. It is our hope that our experiences may help other Western teachers adapt more rapidly to a Chinese education environment and maximize the impact of their efforts.

Keywords: Chinese learner; teacher mobility; internationalization; cultural understanding

R. D. Weinstein, J. O'Brien, E. Char, J. Yost, K. R. Muske, H. Fulmer, J. Wolf and W. Koffke 1023–1030 A Multidisciplinary, Hands-on, Freshman Engineering Team Design Project and Competition

To introduce engineering students to multidisciplinary team work and the principles of engineering design early in their educational careers, a freshman design project and competition was developed. This project and competition required skills typically associated with the four engineering departments (the Departments of Chemical Engineering, Civil and Environmental Engineering, Electrical and Computer Engineering, and Mechanical Engineering) in the College of Engineering at Villanova University. Students were required to build a model car with proper gearing, construct a bridge, and supply power through an electrochemical reaction to complete a specific set of tasks. Teams could only use the limited materials supplied to them. The competition involved an aesthetics contest, a race (including a hill), a load pull, and a load test of the bridge. The project emphasized teaching the freshmen engineering students about team work, open-ended design issues, long-term deadlines, creativeness, the multidisciplinary nature of engineering, as well as the 'fun' of engineering.

Keywords: Multidisciplinary design, first year design, team-based design, hands-on project.

Y. V. Zastavker, J. D. Crisman, M. Jeunette and B. S. Tilley 1031–1042 'Kinetic Sculptures': A Centerpiece Project Integrated with Mathematics and Physics

An integrated set of courses, or Integrated Course Block (ICB), developed for incoming first-year students at the Franklin W. Olin College of Engineering, is presented. Bound by a common theme of 'Kinetic Sculptures', the individual courses in this ICB are mathematics (single variable calculus and ordinary differential equations), physics (kinetics and dynamics of linear and rotational motion, thermodynamics and fluids), and an open-ended engineering project. The project part of the ICB allows students to explore the motion through the design of kinetic (moving) sculptures while utilizing the mathematics and physics concepts learned in the accompanying courses. This paper considers the 'Kinetic Sculptures' ICB from the pedagogical and epistemological points of view by presenting its implementation and discussing the results and analysis of three student surveys taken during three semesters, and seven semesters after participating in the ICB.

Keywords: first-year design experience; integrated curriculum; centerpiece project; kinetic sculpture

B. A. Foss and T. I. Eikaas 1043–1052 Game Play in Engineering Education—Concept and Experimental Results

Dynamic simulators combined with educational games may create a new and improved learning culture by taking advantage of the new knowledge and skills of today's students obtained from extensive use of interactive computer games. This paper presents a design basis and a set of online learning resources based on dynamic simulators that takes advantage of game-related features. The e-learning resources are used in basic engineering courses. Feedback from approximately 1200 engineering students is analysed, the main conclusion being that students clearly view game-related learning resources as having a positive learning effect.

Keywords: dynamic simulation; games; engineering education; e-learning; user feedback.

J. M. Montero, R. San-Segunda, J. Macías-Guarasa, R. de Córdoba and J. Ferreiros 1053–1062 Methodology for the Analysis of Instructors' Grading Discrepancies in a Laboratory Course

This paper introduces a new methodology to analyze grading discrepancies in PBL software-engineering courses with a high student-to-faculty ratio. The methodology is based on a quantitative analysis of the more relevant software features according to the grades assigned by each instructor. In order to reduce the discrepancies detected, a new grading consensus has to be built, and automatic analysis tools must assist the instructors when grading. The evaluation of the methodology in two academic years revealed a 62% reduction of the grading discrepancies, achieving an average inter-instructor discrepancy of 0.10 in a scale from 0 to 1.

Keywords: grading discrepancies; software quality analysis; biases in assessment; project-based learning; massive laboratories; automatic analysis of grades.

A. García-Beltrán and R. Martínez 1063–1069 Web Assisted Self-assessment in Computer Programming Learning Using AulaWeb

This work discusses some issues associated with Web assisted self-assessment of the computer programming skills of first-year undergraduate engineering students. The self-assessment exercises are meant to encourage and motivate them rather than to assess them. The whole system interactivity, based on a client-server architecture, is carried out by means of a computer connected to the Internet with a Web browser. Practical issues of constructing suitable tests and their set up, implementation and results are described. Finally, the results of a survey of students' perceptions and the influence of these on future developments are presented.

Keywords: teaching/learning strategies; programming and programming languages; evaluation methodologies; interactive learning environments.

P. S. Steif and M. Hansen 1070–1076 Comparisons Between Performances in a Statics Concept Inventory and Course Examinations

Multiple analyses of results are presented from the Statics Concept Inventory, a multiple choice test assessing conceptual knowledge in engineering statics. Results are based on the administration of this test to 1331 students in ten classes at seven US universities during the 2004–2005 academic year. Evidence confirming the validity and reliability of the test is offered. Detailed comparisons are made between inventory scores and performance on course examinations, including evaluations of how inventory sub-scores on specific concepts correlate with performance on certain types of problems. Finally, based on analysis of the prevalence of various answer choices, common misconceptions are identified.

Keywords: statics; assessment; multiple choice test; test administration

T. A. Solzak and A. A. Polycarpou 1077–1096 Engineering Outreach to Cub Scouts with Hands-on Activities Pertaining to the Pinewood Derby Car Race

Since the Pinewood Derby (PWD) began more than fifty years ago, it has been one of a Cub Scout's first encounters with engineering principles. The PWD is an event in which seven- to eleven-year old Cub Scouts, with help from parents or leaders, construct a car out of a simple block of wood, four nails acting as axles, and four plastic wheels to race down a track under the power of gravity. Concepts such as friction, energy, roughness, and dynamics are indirectly learned as a result of a car's performance. To promote engineering education to elementary-level children, these concepts are taught to Scouts and their parents through the use of an outreach program, the organization, methods, and assessment of which will be discussed in this paper. Consisting of several stations to demonstrate the effects of rolling and sliding friction, wheel alignment, and weight distribution, the outreach program allows the Scouts to experience first hand how they can improve their car's performance. Hands-on activities as well as actual data also help keep the Scouts interested and motivated to build the most optimized car, and concurrently learn basic engineering principles. Since the PWD is held annually among hundreds of groups internationally, outreach programs have the potential of impacting thousands of Scouts every year and provide a basis for continued interest in engineering.

Keywords: outreach; Cub Scouts; tribology; Pinewood Derby; workshop

L. Yilmaz 1097–1104 Expanding Our Horizons in Teaching the Use of Intelligent Agents for Simulation Modeling of Next Generation Engineering Systems

Multi-agent systems are advocated as a model for designing complex, distributed engineering systems. Yet the practice of teaching the use of intelligent agents in modeling and simulation of next generation open, dynamic, adaptive, and intelligent engineering applications is still in its infancy. In this paper we present a unified and coherent framework for teaching a graduate level agent-directed simulation course for computer science and engineering students. The framework aims to: (1) promote extending our horizons by introducing multiple dimensions for the use of agents in simulation; (2) emphasize focusing on teaching the theory, methodology, and fundamental principles underlying the agent-based modeling framework, and (3) suggest a shift from a predictive modeling worldview toward a new computational epistemology perspective that advocates exploratory experimentation with agent-based models. Based on these premises, a synopsis of the structure, delivery strategy, and the underlying rationale for the design of the course are presented.

Keywords: agent-based simulation; modeling and simulation; multi-agent systems; agents; education

M. Barut, M. B. Yildirim and K. Kilic 1105–1114 Designing a Global Multi-Disciplinary Classroom: A Learning Experience in Supply Chain Logistics Management

Global competition has created multinational supply chains where raw materials production, marketing, and consumption can be in different countries in order to achieve cost-effective production and higher customer service levels by taking a systems approach to supply chain management. Therefore, a key to successful management is acquaintance with interdisciplinary multicultural environments, and with utilization of communication technologies. In this research, a global learning environment for industrial engineering and business students was designed, implemented, and evaluated.

Keywords: global learning, supply chain management, global teams, case study.

M. P. Caine, R. Jones and A. R. Crawford 1115–1120 Developing an Industrially Supported Sports Technology Degree Programme: a Case Study

This paper provides an overview of the development and implementation of a three-year industrially supported Sports Technology Bachelor Degree Programme (with an optional placement year in industry) from within the School of Mechanical and Manufacturing Engineering at Loughborough University, UK. The paper describes how engagement between course providers, industry and students has been encouraged and integrated into the curriculum. It is highlighted that the degree programme has flourished as a direct result of the already strong research activities in this area. Attention is given to the structure and content of the programme, links and discussions held with the sporting goods industry and the aspirations and career destinations of students and graduates. We have initiated many industry activities and believe that this is a key factor in attracting increasing student numbers. Examples include, one-year student placements in industry, industry sponsorship of undergraduate projects, extensive donations of equipment for teaching purposes, ongoing input from a departmental industry advisory board and a programme steering group that includes senior industry, academic and sports governing body representatives. In addition, industry are involved directly in teaching which includes visiting lectures, site visits and factory tours. Emphasis is given to how the needs of industry have been accommodated and how industrial support was sought and subsequently integrated into the programme. Insights gained from student feedback forms are discussed. It is hoped that the paper will be of interest to others operating similar programmes and perhaps more importantly to those currently considering how to work co-operatively with industry to enhance engineering education for undergraduate students.

Keywords: sports science; sports engineering; undergraduate; admissions statistics.