

# The International Journal of Engineering Education

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### Part I—Special Issue on Nanotechnologies

Guest Editor: Jane P. Chang

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| <b>M. S. Wald</b>    | 485     | Editorial   |
| <b>Jane P. Chang</b> | 486–487 | Challenges in Engineering Education of Nanotechnologies |
| <b>M. C. Roco</b>    | 488–497 | Nanotechnology—A Frontier for Engineering Education     |

*The preparation of a nanotechnology workforce for the next decade is a major challenge for the progress of this new technology. It is estimated that about 2 million workers will be needed worldwide in 10–15 years from now. Most of the major disciplines converge at the nanoscale toward the same building blocks, principles and tools of investigation. This paper outlines key US education and training activities in the general context of the National Nanotechnology Initiative that was announced in January 2000. Investigation of systems at the nanoscale requires an increase role of engineering education. Specific education models and the institutionalization of nanotechnology curricula in grades K to 12 and academic institutions are recommended for achieving a modern education system.*

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| <b>Viola Vogel and Charles T. Campbell</b> | 498–505 | Education in Nanotechnology: Launching the First Ph.D. Program |
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*The University of Washington's Center for Nanotechnology has launched the nation's first doctoral degree program in nanotechnology, an undertaking designed to prepare students as leaders in a world in which scientific discovery and exploitation of nanoscale phenomena and the engineering of the very small will carry the next industrial revolution. The program puts in place a Ph.D. nanotechnology track tied closely to other science disciplines. Nine departments take part, and students will earn concurrent degrees in nanotechnology and in a discipline of science, engineering or medicine. The effort is funded by a National Science Foundation's Integrative Graduate Education Research Training program.*

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| <b>Robert W. Kelsall</b> | 506–511 | The Masters Training Package in Nanoscale Science and Technology |
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*The Masters Training Package in Nanoscale Science and Technology at the Universities of Leeds and Sheffield is the first graduate level taught course in this subject area in the UK. The course is highly interdisciplinary, involving staff from six academic departments across the two universities, and is based in an interdisciplinary research centre which provides an ideal inter-departmental, research-oriented environment. In its first year, the course has attracted highly motivated students from a range of disciplines, including physics, chemistry, electronic engineering and materials science.*

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| <b>J. G. Shapter, M. J. Ford, L. M. Maddox and E. R. Waclawik</b> | 512–518 | Teaching Undergraduates Nanotechnology |
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*The first nanotechnology undergraduate degree in Australia was established at Flinders University two years ago. In this paper we present our experience of developing and delivering this degree in a climate where 'traditional' physical sciences are under considerable strain. We will discuss the motivation for this initiative, structure of the established course, and educational issues relating to its development.*

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| <b>Emily Allen, Stacy Gleixner, Greg Young, David Parent, Yasser Dessouky and Linda Vanasupa</b> | 519–525 | Microelectronics Process Engineering at San Jose State University: A Manufacturing-oriented Interdisciplinary Degree Program |
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*San Jose State University's new interdisciplinary curriculum in Microelectronics Process Engineering is described. This baccalaureate program emphasizes hands-on thin-film fabrication experience, manufacturing methods such as statistical process control, and fundamentals of materials science and semiconductor device physics. Each course of the core laboratory sequence integrates fabrication knowledge with process engineering and manufacturing methods. The curriculum development process relies on clearly defined and detailed program and course learning objectives. We also briefly discuss our strategy of making process engineering experiences accessible for all engineering students through both Lab Module and Statistics Module series.*

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| <b>Paul M. Hallacher, Douglas E. Fenwick and Stephen J. Fonash</b> | 526–531 | The Pennsylvania Nanofabrication Manufacturing Technology Partnership: Resource Sharing for Nonotechnology Workforce Development |
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*The Pennsylvania Nanofabrication Manufacturing Technology (NMT) Partnership was established in 1998 with support from the Commonwealth of Pennsylvania. Through the NMT Partnership, the \$25 million dollar equipment base of the Penn State Nanofabrication Facility and its staff are shared with community colleges and other Pennsylvania colleges and universities to enable these institutions to offer degrees in nanofabrication. In addition to providing semester-long, hands-on educational experiences for students from community colleges and other institutions, the NMT Partnership also offers professional development workshops in nanofabrication for educators, and nanofabrication 'chip camps' for middle and high schools students. This year, the NMT Partnership received a NSF award as a Regional Center for Manufacturing Education in Nanofabrication.*

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| <b>Z. Weiss, P. Wyslych, M. Kristková, D. Havlová and P. Capková</b> | 532–538 | Analysis of Nanostructured Materials Ph.D. Course |
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*The Ph.D. student course includes four areas oriented on analytical training in the field of nano-scale materials. The first one is focused on the computer modeling of nano-structured systems using the molecular simulation in Cerius2 modeling environment, the second deals with nano-scale surface analysis using Atomic Force Microscopy, and the third brings advanced information about crystal structure analysis using single-crystal and powder X-ray diffraction methods. The last area is oriented on analysis of materials by electron microscopy techniques. The Ph.D. student analytical course includes both theory and applications (training) of individual analytical procedures for various nano-structured materials (for example, nanotubes, intercalated and grafted clays, graphite, silicon wafers, polymer/clay nano-composites, and metallic thin multilayer materials).*

**Anindya Dasgupta, Raymond A. Matthes, Christos G. Takoudis and Sanjit S. Dang** 539–549 Web-based Instruction on the Fundamentals and Design of Micro- and Nanoelectronic Processes: Innovations, Challenges and Benefits

*The focus is a web-based course on the fundamentals and design of micro- and nanoelectronics processing developed two years ago and offered once a year. To our knowledge, this is the first chemical engineering course on micro- and nanoelectronic materials and processing ever to be offered on the Web. Through this graduate/advanced undergraduate web-based course, we present and discuss related innovations, challenges and experiences on the impact the Internet is having in the field of engineering education, new technologies in engineering education, and preparing students for the challenges of nanoengineering in the 21st century.*

**S. Michael Condren, Jonathan G. Breitzer, Amy C. Payne, Arthur B. Ellis, Cynthia G. Widstrand, Thomas F. Kuech and George C. Lisensky** 550–556 Student-centered, Nanotechnology-enriched Introductory College Chemistry Courses for Engineering Students

*Nanotechnology provides numerous examples of materials and devices that can be incorporated into the classrooms and laboratories of introductory college chemistry courses. These examples illustrate tools used to investigate and shape matter at the nanoscale and materials and devices whose properties depend on nanoscale control. Engineering students in these courses can benefit by seeing applications of chemical and physical principles in modern technological contexts and by developing skills that will enable them to participate in fields that involve nanotechnology. Pedagogical methods and assessment and evaluation tools that reflect inquiry-based approaches to instruction can be aligned with nanotechnology exemplars in these courses.*

**Timothy Chang, Puttiphong Jaroonsiriphan and Xuemei Sun** 557–565 Integrating Nanotechnology into Undergraduate Experience: A Web-based Approach

*This paper describes a web-based distance experiment on the control of a two-degrees-of-freedom (DOF) monolithic piezoelectric actuator. This actuator is part of a six-DOF manipulator [1] capable of linear resolution to 2 nanometers and angular resolution to 1 arc-second [2]. The LabVIEW/DataSocket approach has been adopted in this implementation to enhance streaming of live data as well as to facilitate the interaction among the various system modules such as PC platform, digital signal processor board, client/server interface, and the nanopositioner. Besides a LabVIEW-based client program which requires the remote PC to have LabVIEW installation, a Web browser-based client plug-in has also been generated for students/users who do not have programming experience with LabVIEW. Test results for multi-client access have been very favorable. Reliable real-time control bandwidth of the two-DOF nanopositioner was detected at about 3 KHz, adequate for undergraduate control experiments. The same client/server interface can also be applied to a wide range of experiments for 24/7 and global access.*

## Part II—Papers in Mechanical, Industrial and Manufacturing, Chemical, and Ecological Engineering Education

### Mechanical Engineering

**David Elata and Isaac Garaway** 566–575 A Creative Introduction to Mechanical Engineering

*This paper describes a new introductory course developed at the Technion for freshmen Mechanical Engineering students. Through unconventional teaching methods, this course provides a clear overview of the different fields within Mechanical Engineering, and also provides a clear description of the engineer's work. By challenging the students to design devices that perform specific tasks, this course raises their awareness of scientifically relevant physical phenomena they encounter later in their studies. At the same time, it elucidates the importance and necessity of analysis tools such as simplified physical models of a system and mathematical formulation of its response. Working in small teams, the students conduct research and development and consult with senior peers and faculty, to optimize the design and construction of their devices. The quality of the devices they build is then measured within a framework of a dramatic competition between all teams. The competitive spirit is used to increase the motivation and involvement of the students, and to promote creativity. Following the competition, the projects are scientifically analyzed in class, and relevant physical models and related mathematical tools are presented. It is demonstrated that simple modeling and calculations may help in identifying and characterizing optimal solutions for engineering problems. In addition, the students are required to analyze the design process they have conducted, and many of the conclusions they draw are valid lessons that are relevant even to professional engineers.*

### Industrial and Manufacturing Engineering

**George Hassapis** 576–583 Teaching Industrial Control with the Assistance of a Web-based Interactive Simulator of Distributed Control Systems

*This paper addresses the issue of teaching the implementation of industrial control by using an interactive simulator of a typical distributed computer control system (DCS). This simulator is able to run in a web environment, which imposes an instructional model and provides access to hypertext. According to this instructional model, teaching of the industrial control implementation is done through the simulation of an application, which is wrapped-up with the relevant theory. The simulator is able to simulate the execution of the software that realizes the regulatory control algorithms, the startup and emergency control functions of an industrial process as well as the functions of the operator's station.*

**W. B. Lee, J. G. Li and C. F. Cheung** 584–596 Development of a Virtual Training Workshop in Ultra-precision Machining

*This paper presents the development of a virtual training workshop (VTW) for supporting training of engineering personnel to acquire the theoretical know-how, practical skills and the problem troubleshooting techniques on the usage of ultra-precision machining and inspection facilities, which might not be affordable in conventional training workshop. The architecture, underlying theoretical basis and implementation aspects for the development of the VTW are described. Experimental work for realizing the capability of VTW together with the future development of a distributed virtual training environment (DVTE) are also discussed.*

### Chemical Engineering

**Laureano Jiménez, Allan D. Mackie and Jaume Giralt** 597–606 Operation and Control of a Distillation Column as a Tool to Teach the 'Real Problem'

*This paper examines the benefits provided to undergraduate students by the dynamic operation of a fully automated pilot plant. The experiment was designed to foster a deep understanding of control concepts and to offer the opportunity to deal with real control devices and problems. The students need to identify and set the proper control configurations, tune the control parameters and test the controllability for typical process upsets following a stop and go experimental organization. We believe that this hands-on approach is an indispensable step in the formation of our future engineers.*

*As interest develops in ecological engineering, there is a need for the development of projects suitable for teaching. Ecological engineers must learn how to deal with ecological relationships on both a quantitative and qualitative level. This paper describes a project that takes advantage of the synergy possible between graduate students and undergraduate students. The project focuses on the design and implementation of both physical and virtual models of a sealed aquatic microcosm.*