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Section I
Special Issue
Current Trends in Nanotechnology Education

Guest Editors
Wei-Fan Chen and Tony Jun Huang—The Pennsylvania State University, USA

This article describes the integration of design aspects of nanopositioners into an undergraduate, Automatic Controls (AC) course in the Mechanical Engineering (ME) Department at the University of Washington (UW), Seattle. The course development is part of an overall effort to integrate nanotechnology into the undergraduate curriculum at UW through a mixture of new and existing courses. The current article addresses challenges in adding new content in existing courses (such as AC) by integrating nanopositioner design issues with concepts already taught in the course (such as control design to increase bandwidth), and the use of homework (HW) to allow students to explore the application of course concepts into the nanotechnology area. Learning assessment results are presented to demonstrate that students were well able to meet the learning objectives.

Keywords: nanotechnology; automatic control; piezoelectric devices; homework

This paper presents a systematic visual approach to teaching concepts in nanotechnology. Five types of mathematical models are used to generate visual, interactive simulations that provide a powerful software environment for virtual experimentation. The nanotechnology content areas covered by this approach are discussed. A variety of instructional strategies for effective use of these simulations are discussed. Preliminary results from a pilot study at the college level demonstrated the potential of this approach for improving nanotechnology learning.

Keywords: nanoscience; nanotechnology; computer simulation; scientific visualization; science education; knowledge integration

This study examined how science and engineering students with different academic level perceived and experienced computational simulation tools for nanotechnology in terms of learning outcomes, evidence of learning, pedagogical approaches, and ease of use. The simulation tools used in this study are part of the research and learning resources in nanoHUB.org. Data were collected by anonymous and optional online survey questionnaire given to 312 science and engineering students with access to nanoHUB.org. The quantitative and qualitative analyses showed that overall, graduate and undergraduate students reported positive experiences of nanoHUB.org simulation tools and their uses. However, differences were observed in the way undergraduate students reacted to the computational simulations as compared with graduate students. Possible explanations for these differences and suggestions to close this differential gap were also discussed. Potential explanations for these differences are that undergraduate students may have not fully developed graphical literacy skills, may lack the prior knowledge required at the time they interact with the tools, or tools may be too complex. Suggestions to overcome some of these difficulties include the development of well integrated curricular materials, the application of frameworks for technology-enhanced support for inquiry learning, and the use of just-in-time instructional supports together with the simulation tools.

Keywords: computational simulations; nanoHUB.org; engineering education; cyber-enabled learning

The ability to explore the physical world at the nanoscale has opened up an affluence of technological advances with the potential to improve human life. Further, it has been complemented with significant advances in simulation-based engineering and science (SBE&S). Having become a crucial part of the present infrastructure, SBE&S is central to the application of advances in the conductance of scientific research and engineering practices. These facts clearly signify the need to integrate the use of computational simulation tools in 21st century engineering education curricula as one way to bridge the gap between school engineering and work engineering. The guiding research questions for this study are: (a) What technological pedagogical content knowledge do professors have for incorporating computational simulation tools to convey nanoscale science and engineering-related concepts and practices? and (b) How do students react to an instructor's technological pedagogical content knowledge with computational simulation tools? This study coupled the methodological framework of a case study with the theoretical framework of TPCK. Open-ended interviews, classroom observations, and document analyses were conducted with six engineering professors teaching undergraduate and graduate courses related to nanoscale science and engineering. Thirty-three students of these courses were also interviewed. Analyses present detailed descriptions of how instructors integrated computational simulation tools to support the learning of nanoscale-related concepts. Findings revealed that computational simulations were perceived by students as effective learning tools. Also revealed was that students continued to confront difficulties when interacting with these tools. Implications for education and educational research in engineering relate to the development, the research and implementation scaffolds, and the transparency at the physical/conceptual, mathematical, and computational levels to understand and then overcome student difficulties in learning with computational simulation tools.

Keywords: computer simulations; computational simulations; engineering education; technological pedagogical content knowledge; nanoscale science and engineering; qualitative research methods

Over the past few decades, scientific disciplines have changed significantly with the introduction of new and complex aspects of research, particularly in the area of nanoscience and nanotechnology (N&N). Efforts to develop science education programmes in N&N area to adopt these complex changes are also evident from recent literature and educational reports. However, these attempts are focused towards identification and inclusion of contextual scientific knowledge in the curricula and very little is understood about the attributes knowledge, skill and competence necessary to successfully undertake N&N research. Identification of these attributes is important so that the contextual scientific knowledge can be embedded in the curricula more effectively. Also, it is uncertain whether this growing research area requires researchers that have studied specialised undergraduate or postgraduate N&N programmes or traditional science and engineering disciplines. In other words, is N&N research multidisciplinary, interdisciplinary or will it develop into a unique discipline is not clear. To address this question, this qualitative study will examine the postgraduate researchers' experiences of researching in N&N area. Studying how the researchers understand, interpret and describe their experiences, we can achieve a new; or; at the very least a wider understanding of what N&N research is; and how the postgraduate researchers use their education and training to research in this area. This in turn will inform the curriculum development at the undergraduate and postgraduate levels and address the issues of whether we should have specialised undergraduate N&N programmes or simply different distinct science and engineering disciplines coming together.

Keywords: science curricula; phenomenology; interdisciplinary skill

There is a critical need for effective instructional methods that help future scientists and engineers participate in resolving societal and ethical issues brought about by innovation. This paper reports on the results of a multi-disciplinary, project-based instructional approach for college-level science and engineering students that integrated nanotechnology content-learning with the practical, social and ethical problems of nanotechnology application. Using a mixed method, pre- and post-instruction design the study examined students' perspectives and reasoning about the societal effects of nanotechnology discoveries. The results indicated that students had a cautiously optimistic attitude and that they maintained this position throughout the course. However, their reasoning for their attitudes noticeably changed after instruction. The detailed reasoning-analysis revealed students' deep-seated beliefs about the societal effects of nanotechnology discoveries. It also indicated the effectiveness of our instructional method to help students critically examine these prior beliefs and orientations. In specific, the findings indicate the need to consider quantitative and qualitative indicators of attitude about the social effects of scientific and engineering innovation in order to prepare students for the 21st century workforce. These findings guide our refinement of the instructional approach and can be informative for colleagues planning similar interventions in their curricular offerings.

Keywords: nanotechnology ethics; socio-scientific issues; multi-disciplinary education; student attitudes; reasoning about attitudes

Nanoscience education requires learning in a meaningful context. In the NanoLeap unit *Investigating Static Forces in Nature: The Mystery of the Gecko*, high school students were introduced to an interdisciplinary approach in nanoscience. As a summative assessment, 100 high school students wrote essays responding to the question, 'How does the gecko adhere to a ceiling?' Using design based research and qualitative theme analysis, researchers analyzed 100-student essay using the original scores given by their teachers. The findings supply four major themes and five subthemes that highlight trends in student understanding. Expectedly, students accurately described physical characteristics of the gecko, surfaces, and the coinciding principles of force at the nanoscale level. With language, more students used colloquial terms to describe scale than used references to numbers. Unexpectedly, almost half the students used words to describe their sense of wonder and value of nanoscience to understanding their world.

Keywords: nanoscience; assessment; qualitative; essay assessment; science writing; science assessment, high school

In recent years, nanotechnology research has become a popular topic of interest, and the development of nanotechnology talent is also considered highly important worldwide. The Taiwan government has developed related policies and initiatives that support advanced and innovative nanotechnology research and budgets on human resource development in this field. It is our belief that the earlier students develop their awareness and interests in nanotechnology, the higher the possibility that they will become accomplished engineers in this field. Connected to this scenario, a nano-biotechnology summer camp was initiated in 2009 to take advantage of David Kolb's experiential learning theory. The curriculum integrates conceptual knowledge into practical activities for a complete learning experience. Fifty-two senior high school students attended this camp, and each student completed a questionnaire survey aiming to explore students' responses to this learning experience. Results of the present study revealed that the students were satisfied with the teaching and learning in the camp. They were also largely in favor of both 'hands-on experiments and laboratory experiences' and believed that more learning and better experiences occurred through these two course activities. This paper further discusses some important issues observed and suggests guidelines for future research and practice in nano-technology training.

Keywords: nano-biotechnology; summer camp; curriculum design; senior high school students; learner's attitudes

Lecture demonstrations can be a significant aid to learning, when coupled with appropriate teaching methods and conceptual knowledge. However, in-class experimental demonstrations of core concepts in nanotechnology, such as self-assembly of molecular systems, is exceptionally challenging under poorly controlled classroom conditions. In this work, I demonstrate the use of soap bubbles as easily visualized, accessible and relatively robust examples of molecular systems, that are already familiar to students, yet can be used to illustrate complex principles of self-assembly. Utilizing dynamic soap bubble sculptures, this work illustrates a simplified framework within which to teach molecular self-assembly in nanoeducation outreach programs at the secondary school level. Student learning and interest in nanoscience was assessed via an ad hoc survey to determine the suitability and effectiveness of soap bubbles as learning tools for this target audience. The results demonstrate that even academically strong students at the secondary level had largely not considered the link between molecules and soap bubbles, but described a high level of intrinsic interest in the subject material. Self-assessed levels of concept comprehension were high, and students described an increased interest in pursuing studies in the physical sciences and specifically within nanotechnology.

Keywords: bubbles; soap; sculptures; self-assembly; molecular; demonstration; lecture; experiment; classroom; education; nanotechnology

Section II
Contributions in: Education Research, Outreach, Mobile Learning, Educational Technology, Mechatronics, Bioprocess, Problem Based Learning, Active Learning, Teaching Grant Proposal Writing, Fluid Mechanics, Mechanical Training, Civil Engineering, Simulation, Soft Skills, International Perspective

The Center for the Advancement of Engineering Education (CAEE) conducted research on the learning experiences of engineering undergraduates, the teaching practices of engineering faculty, and methods to build capacity to teach engineering and conduct high-quality engineering education research. This paper has two goals: to present a sample of key findings from these multiple research threads and to highlight the various tools and processes developed by the CAEE research team that are available for use by others. These resources include survey, interview, and design task instruments, as well as a year-by-year guide to the development and implementation of the Academic Pathways Study (APS), CAEE's in-depth study of engineering undergraduates. A more extended discussion of findings is available in CAEE's final report, *Enabling Engineering Student Success*. The final report and the tools for researchers can all be viewed and downloaded through the CAEE website at http://www.engr.uw.edu/caee/. CAEE was funded by the National Science Foundation from 2003 to 2009.

Keywords: engineering education; engineering undergraduate learning; engineering teaching; research instruments; early-career professionals; engineering practice; educator decision making; engineering education research community

A large-scale collaborative learning project involving first-year engineering students and fifth graders from local schools was developed and implemented during the fall of 2010. Entitled 'I2D2: Imagination, Innovation, Discovery, and Design,' the program's success in the first year inspired program continuation during the 2011 school year and beyond. The program was developed for an intended dual benefit of both college and intermediate school students. The college students worked with the intermediate school students on LEGO® activities and then had the opportunity to talk with them about their ideas for a Robotic Pet—in this way serving as a 'customer' to a first-year engineering design project. For the intermediate school students, the goal was to offer exposure to a university setting and instill an interest and recognition of the engineering/scientific process to help prepare them for their science fair projects. The results indicate that while intermediate school students are already interested in going to college, exposure through hands-on activities with college students can increase their interest level in STEM fields. For the first-year engineering students, differential responses were indicated by women and students with younger siblings. Finally, the intermediate school teachers were interviewed after the event for their feedback and reaction to the event. Future plans for improved program administration and assessment are discussed.

Keywords: K-12; outreach; first-year engineering design; STEM education

There are exciting new opportunities for mobile learning in structured and semi-structured out-of-classroom activities using inquiry-based or project-based pedagogies. We present ongoing research on mobile access to context-relevant digital library resources using mobile interfaces. This project leverages the *Engineering Pathway*, a digital library of high-quality teaching and learning resources for applied science and math, engineering, computer science/information technology and engineering technology for K-12, higher education and beyond. We build on a previous user needs analysis of teachers, parents and students involved with mobile learning and present two mobile prototype applications that address these needs. *Simple Machines in Your Life* use a PDA to engage elementary school girls in learning about the simple machines in their surroundings. *GreenHat* uses a GPS-enabled Smartphone to encourage exploration of the natural environment through expert's perspectives. These two cases evaluate the benefits of technological features and their limitations. Lessons learned and recommendations for future improvements are summarized.

Keywords: mobile learning; engineering education; mobile devices; digital library, mobile library; science education

In this paper we present a successful implementation of a new software environment for learning and knowledge assessment. We introduce a new kind of gadget that is appropriate for inclusion in learning environments. The proposed gadgets are based on individualized interactive graphics tasks that are similar to educational Java applets. However, the usual graphical applets are not individualized: they do not have a defined goal for the learner and they do not evaluate the solution to a given graphical task. Using several examples, we present the development of the gadgets. The development of gadgets must address two problems: how to create and present an individualized task to the student and how to evaluate the student's solution, especially when multiple solutions are possible or solutions can be partially correct. The tasks that are described in this paper are intended for learning and knowledge assessment in computer graphics courses. However, the proposed concept is applicable to many other courses and educational activities. To study the influence of the proposed software environment on student learning and performance, we provide experimental results from several years of student use of different gadgets in preparation for mid-term and final exams and we analyze and discuss the findings. In addition, each year a selected group of students was given the opportunity to develop and implement several gadgets that were then used by their peers for learning and knowledge assessment. We discuss the results obtained and the experience gained.

Keywords: educational technology; computer graphics software; unsupervised learning; programming environments

The mechatronics course for undergraduate and graduate level engineering students, a technical elective offered by the Department of Mechanical Engineering at Clemson University, promotes the exploration of mechatronic system integration concepts. The course objectives are to create a collaborative environment for the multi-disciplinary engineering students, provide hands-on experience with mechatronic systems, develop teamwork, leadership, and project management skills, and prepare the students for

current industry standards. The holistic course activities include studying fundamental knowledge from mechanical, electrical, computer, industrial, and robotics engineering, which is re-enforced through laboratory experiments and semester long projects. The design projects foster collaborative teamwork activities and offer the opportunity for in-depth experience with sensors, actuators, and material handling systems. The course assessment, which establishes a basis for continuous improvement, considers student performances, their written feedback on qualitative surveys, and feedback offered by an advisory panel composed of industry experts and faculty members. The assessment methods evaluate the performance of students and the course to further improve the overall learning experience. Past evaluation results have shown that the students consistently improved in four learning goals and the advisory panel offered favorable remarks about the course.

Keywords: mechatronics; classroom concepts; laboratory experiments; design projects and assessment

The newly created concentration in bioprocess engineering at East Carolina University was developed with a novel curriculum designed to engage the students and improve their mastery of concepts using proven pedagogical approaches. This study presents the development of nine instructional modules for three bioprocess engineering courses (three modules per course) and the assessment of the effectiveness of the instructional modules. Each module is initiated by presenting the students with a challenge question. The students work on the challenge by completing a cycle of exercises that are designed to engage critical thinking and self-assessment, and for making connections among concepts within the course. The module culminates with students presenting their 'answer' to the challenge through various means, such as a report, poster, video, exam, etc. Of the nine modules, three are integrated through the different bioprocess engineering courses. This integration provides a theme for the students to make connections among the different courses and to transfer concepts to new situations. Our work sought to provide the answers to two research questions: 1) Did the students master the facts, skills, and concepts of bioprocess engineering through the use of the modules? and 2) Did the use of the modules create an effective How People Learn (HPL) learning environment within the three bioprocess engineering courses? The results of the assessment indicate that the modules were effective in developing the students' mastery of the facts, skills, and concepts across all three courses and created a very effective HPL learning environment in two of the three courses.

Keywords: bioprocess; problem-based learning; challenge-based learning; legacy cycle; concept map; How People Learn

This paper investigates the effect of Problem Based Learning (PBL) compared to conventional approach, on students' knowledge acquisition, specific to concepts, principles, and procedures. This study employed an experiment, a pre-test, and a post-test, with control group designs. Participants comprised 53 first semester electrical engineering undergraduate students, who are attending the Electrical Technology (ET101) module. Participants completed a set of pre-test and a set of post-test multiple choice questions, covering a two-unit syllabus after ten weeks of treatment. Results suggested that student within the PBL group outperformed their counterparts in knowledge acquisition of principles and procedures. However, students using the conventional approach performed much better in knowledge acquisition of concepts. In terms of the whole structure of concepts, principles, and procedures, PBL enhanced students' knowledge acquisition in the electrical engineering course, compared to the use of conventional approach. This study also discusses the implication of PBL within engineering education.

Keywords: Problem Based Learning; engineering education; electrical engineering; knowledge acquisition

Nearly all published literature on grant proposal writing focuses on suggesting best practices for, or providing general guidance on, grant proposal writing (i.e., what a grant writer should do and should not do), rather than on pedagogy (i.e., how to teach grant proposal writing). To fill this gap, a student-centered active learning approach to teaching grant proposal writing is developed in the present study. This approach combines three types of active learning activities: think-pair-share discussions and reflections, mock panel review, and student development of a full proposal. This approach was implemented and assessed in a grant proposal writing course in a Ph.D. in Engineering Education program at Utah State University. Questionnaire surveys were administered in two semesters to assess the effectiveness of this approach. The results show that, on a 5-point Likert-type scale with 1 representing the least effective and 5 representing the most effective, the mean scores of student responses are more than 4.00 for all three types of active learning activities. The mean scores on "student development of a full proposal" activities are the two highest mean scores in both semesters: 4.71 in one semester and 4.63 in another semester. This implies that the most effective method for students to learn how to develop grant proposals is learning by doing, i.e., each student develops a proposal of his/her own.

Keywords: grant proposal writing; students-centered active learning; pedagogy; Ph.D. in engineering education

In the presented study, an experimental set-up for use in an undergraduate fluid mechanics laboratory was designed, built and constructed by a graduate student. Two basic educational objectives were determined for this study: to give a good education to the graduate student as both a graduate teaching assistant and as an engineer, and to create a laboratory experiment for undergraduates. Important aspects of experimental studies were introduced to the undergraduate students by using the built set-up, from understanding the basic theory to performing error calculations. The objectives that were fulfilled for the graduate student's education were evaluated using Bloom's taxonomy. The improvement in undergraduate knowledge on the subject was examined by comparing the scores that the undergraduates attained in oral exams that they took before they conducted the experiments with the scores that they achieved from the reports they prepared after they had conducted the experiments.

Keywords: experiment design; laboratory courses; basic fluid mechanics experiments; graduate teaching assistant education; FLOWNEX

The development, implementation and evaluation of a virtual instrument that allows a detailed diesel engine simulation performance and parametric analysis of the combustion process are described. The stimulus for developing this computer-aided educational tool derives from the continuing need for the engineer to understand and apply mathematical models in engine simulation. The application of software in teaching internal combustion engines can help students to improve their parametric analysis and allow them to understand diesel combustion better. The educational software of Simulation and parametric analysis are developed and visualized using MATLAB code and the designed graphical user interface (GUI) respectively.

Keywords: simulation; combustion; diesel engine

Mechanical workshop training is important in engineering education, which often faces challenges such as the management of a large number of teaching resources, manual and paper-based data collection and the low efficiency and effectiveness of teaching operations. This paper proposes an RFID-enabled Engineering Workshop Training Center (EWTC) by first integrating the Teaching by Examples and Learning by Doing (TELD) principle to enhance the teaching efficiency and effectiveness. ''Teaching by examples'' allows the students to ''see and then remember'', while, ''Learning by Doing'' allows students to ''do and then understand''. Secondly, EWTC uses RFID (Radio-Frequency Identification) technology to convert various resources into smart teaching objects (STOs), which are connected by wireless networks in order to collect real-time information in an intelligent ambience. Finally, it adopts the Service-Oriented Architecture (SOA) model to develop the system architecture to use the real-time RFID data for facilitating different users' operations and behaviors. A real-life case study illustrates how the RFID-enabled EWTC rationalizes a typical mechanical workshop training item in a university. By qualitative analysis, the daily operations of typical end-users, such as teaching supervisors, tutors and students are reengineered and improved into a pedagogical level that is real-time, optimal and specific. A set of statistics implies the upgrade of EWTC in quantitative analysis.

Keywords: RFID; real-time; mechanical workshop training; TELD; engineering education

The Arab World countries are facing major challenges in Civil Engineering professional registration standardization due to the significant differences in the undergraduate curricula in these countries. This paper compared undergraduate civil engineering curricula in Arab countries. A review of the course requirements at 31 universities located in 19 countries was presented. Only universities that follow the American credit hour system are included in the study. Specifically, the study addressed degree requirements related to science, mathematics, general education, free electives, English language, engineering fundamentals, computer proficiency, required civil engineering courses, and technical electives. The study showed that the considered curricula took either 4 or 5 years to complete. The number of credit hours was found to be as little as 131 and as large as 204 credits. The humanities, social science and foreign language requirements at traditional universities were usually very low, whereas the same requirements were almost a full-year of study at Western-style universities located in the same region. Some universities followed a track system, which provided for specialization in one of the various civil engineering disciplines. As a result, the curricula of such universities were loaded with a large number of obligatory technical courses. The Western style universities, on the other hand, were heavy on fundamentals, but gave the student more choices with regard to technical and free elective courses.

Keywords: civil engineering; curriculum development; education; general education; professional registration; technical electives

The engineering profession has traditionally been a technical field based on theoretical and scientific discipline. In addition to the technical knowledge and hard skills, engineers must acquire sufficient soft skills in personal and interpersonal behavior to meet current employment market standards. This research identifies learning deficiencies that hinder the effectiveness of practicing engineers. Based on the ABET (Accreditation Board for Engineering and Technology) criteria, three categories of skills were tested: technical, interpersonal, and personal indicators. Research questions were as follows: Did engineers acquire these skills before graduation? How important are these skills to them as practicing engineers? Are there any differences in their perceptions of gender, work experience, or work location? A sample of 188 engineers who graduated from universities in Lebanon completed an online survey assessing their proficiencies before graduation and after starting their profession. Fifteen engineers were interviewed to gather information about the skills necessary for their career. Although participants reported that they possessed adequate theoretical knowledge and technical skills, noticeable weaknesses in creativity and innovation were found. Interpersonal and personal skills in leadership, management, and multidisciplinary teamwork were the most overlooked aptitudes in college despite their importance in work settings.

Keywords: college preparation; engineering practice; soft skills

The relationship between tertiary education and employment is an important issue that concerns a number of interested parties that include education providers, national education policy makers, industry operators, the undergraduates and their families. In this study, the education and employment relationship were studied from the aspect of the mismatch of acquired (AC) and required (RC) competencies of the electronic engineers in the electronic industry. The competencies were studied from the generic and subject-specific aspects. Respondents from the Malaysian Penang Development Corporation Industrial Areas were involved in this research. The research samples comprised managers, human resource managers, production managers and test managers. Two sets of questionnaires were administered to the participants. The findings clearly showed that there is a common agreement among the managers (employers) on the existence of an AC–RC competencies mismatch. A paired sample t-test between the AC and RC competencies of the soft and hard skills showed they were significantly different. The size of the mismatch of the competencies in ascending order for the soft skills are: ICT skills, Personal qualities, Thinking skills, Interpersonal skills, Management skills, and Communication skills. In the hard skills categories, the size of the mismatch ascends in the order 'Practical usage of the software tools', 'Circuits construction', 'Operate, troubleshoots systems and equipment', 'Process, control and installation', 'Quality and reliability testing'. The overall mismatch of the soft skills was significantly greater than that of the hard skills. The findings of this study highlight the need for the Malaysian Higher Education system to take drastic action to close the gap between tertiary education and employment.

Keywords: graduate mismatch; higher education; acquired and required competencies; labour market

The aim of this paper is to determine the objectives and standards of engineering education in Iran, adopting a global approach. Eight documents and fourteen models of engineering education were analysed using content analysis. In order to define the objectives and standards of engineering education in Iran, common characteristics of the selected documents and models were identified. With regard to the results of the content analysis of these documents, twenty-four objectives in five categories for engineering education were determined. These categories include: knowledge and reasoning in technical and engineering topics; personal skills and attitudes; professional and ethical skills and attitudes; interpersonal skills and attitudes; and skills for developing system, product, or process. In addition, based on the content analysis of fourteen models derived from international consortia and agreements, seven standards including twenty-seven requirements were identified for engineering education. These standards are: the philosophy and objectives of engineering education; the curriculum; the instructional space and facilities; the teaching–learning process; faculty members; students; and assessment and evaluation.

Keywords: engineering education; educational objectives; standards and requirements; globalization; content analysis