

# The International Journal of Engineering Education

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## Special Issue: Instructional Technologies in Engineering Education

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- L. de Marcos, R. Barchino, J. J. Martínez and J. A. Gutiérrez 632–645 A New Method for Domain Independent Curriculum Sequencing: A Case Study in a Web Engineering Master Program

*In e-learning initiatives, sequencing problem concern the arranging of a particular learning unit's set in a suitable order for a particular learner. Sequencing is usually performed by instructors who create a general-public ordered series rather than learner personalized sequences. This paper proposes an innovative intelligent technique for learning object automated sequencing using particle swarms. E-Learning standards are upheld in order to ensure interoperability. Competencies are used to define relations between learning objects within a sequence, so that the sequencing problem turns into a permutation problem and artificial intelligent techniques can be used to solve it. Particle Swarm Optimization (PSO) is one such technique and it has proved to perform well for solving a wide variety of problems. An implementation of PSO for the learning object sequencing problem is presented and its performance in a real scenario is discussed.*

**Keywords:** e-learning; learning object; sequencing; swarm intelligence; Particle Swarm Optimization (PSO)

- M. Laabidi and M. Jemni 646–654 PBAE: New UML Profile Based Formalism to Model Accessibility in E-Learning Systems

*The integration of accessibility in e-learning platforms has become a necessity. Furthermore, the evolution of development technologies and assistive technologies impose constant change and improvements on online educational systems. The application of Model Driven Architecture (MDA) turns out to be the most appropriate method to use to follow this evolution. This paper presents a new formalism based on UML profiles called PBAE, which is used to apply MDA in the development process of accessible e-learning systems. Our goal is to use this formalism to specify all the accessibility requirements to define models of accessible e-learning systems. ArgoUML is used for implementing our formalism.*

**Keywords:** e-learning; accessibility; WAI; MDA; UML profiles; ArgoUML

- C. Alvarez, M. Nussbaum, M. Recabarren, F. Gomez and D. Radovic 655–664 Teaching Communication, Interpersonal and Decision-Making Skills in Engineering Courses Supported by Technology

*Communication, interpersonal and decision-making skills are essential for engineering work and should be explicitly incorporated in engineering curricula. We have tested a constructivist, technology-supported collaborative strategy in engineering courses that is aimed at supporting the teaching of regular subject matter as well as fostering the development of students' communication and social skills. In this strategy, students communicate face-to-face through a social network while supporting their work with handhelds interconnected through a wireless network. Information transfers from the social network to the handheld network and vice versa, meaning that collaborators maintain face-to-face interaction at all times while also being able to obtain and retrieve information. To implement this strategy, a technology tool named CollPad was created and applied in two computer science courses. The qualitative results of the experience show that students found the tool effective in creating an environment that promotes communication, interpersonal and decision-making skills.*

**Keywords:** face-to-face computer-supported collaborative learning; CSCL, participatory classroom; communication skills; social skills; one-to-one learning; constructivist learning; small group learning

- P. Sancho, R. Fuentes-Fernández, P. P. Gómez-Martín, and B. Fernández-Manjón 665–679 Applying Multiplayer Role-Based Learning in Engineering Education: Three Case Studies to Analyze the Impact on Students' Performance

*In this paper we present some results obtained in an ongoing research project aimed at developing a collaborative 3D fantasy virtual learning scenario (which we have given the name Nucleo) for teaching subjects related to computer programming in engineering education and technical schools. Our system has three basic objectives. The first is to induce a change in the students' attitude towards study by placing them at the center of the learning experience. The second is to increase students' motivation by bringing multimedia formats, content interactivity and the aesthetics currently preferred by engineering students into the learning scenario, while at the same time, maintaining a clear focus on the curriculum's learning objectives. The third is to provide a learning environment that simulates the way people work in teams in a real-life professional context, focusing on developing basic teamwork abilities and important soft and social skills. The system is currently being tested in several engineering educational contexts to prove some basic hypotheses. Here we describe the main features of our system, the results obtained in three different cases of study and a discussion about what conclusions can be drawn from them.*

**Keywords:** e-learning; CSCL; problem-based learning; multi-user virtual environments

- S. Kim, M. Cha and J. Hong 680–692 Analyzing Needs, Readiness, and Epistemological Beliefs of Students and Faculty to Implement University 2.0 as Social Platform of Teaching and Learning

*With the advance of social technology, University 2.0 is to bring a user interactive Web 2.0 system into higher education settings, as a more powerful way of constructing and sharing knowledge. For the successful implementation of the 2.0 platform, this study investigated how faculty and students perceived this new learning system by assessing their needs, readiness, and personal epistemology at the College of Bionano. In this study, 10 students and 13 professors participated in a focus group discussion and a survey*

respectively, and both took an Epistemology Questionnaire. According to this study, faculty and student group expressed their opinions on issues such as academic affairs, evaluation, and copyright, and showed disparities in their epistemological proclivities. Whereas the professors had a conservative view of the students' role in knowledge creation and knowledge reproduction, the students needed a change in perception in the educational setting as well as in learning systems. This result implied that the university needs to investigate its constituents' needs, readiness, and beliefs surrounding education so that the recent participative system could effectively contribute to meeting the real needs of learners in the fields of sciences and engineering, as well as in the primary mission of the university.

**Keywords:** Web 2.0; University 2.0; bionano technology; epistemological belief; focus group

**W-J. Shyr**

693–700 Internet-Based Laboratory Platform for Distance Learning in Engineering Education

*This study proposes an Internet-based mechatronics laboratory platform for distance learning in engineering education. The Internet-based laboratory platform enables students remote access to laboratory equipment. This platform established a user-friendly and efficient technology for providing interactive online laboratory experiments for distance students. This study describes the development and use of a novel Website to improve the learning of mechatronics concepts. Preliminary assessment of the laboratory platform was encouraging and demonstrated its effectiveness for helping students understand concepts and master basic technologies for developing Internet-based mechatronics monitoring and control systems. The main contributions of this study are as follows. (1) A distance learning platform is developed and experimentally tested with mechatronics module. (2) Learning exercises are specifically targeted to the objective of the laboratory. (3) Mechanisms that further support the students are developed. (4) The proposed system has an intuitive and convenient platform. (5) The technical aspects of the proposed platform are also presented.*

**Keywords:** Internet-based; mechatronics; laboratory platform; graphical monitoring and control; experimental evaluation

**Y. S. Kim and E. Wang**

701–711 Intelligent Visual Reasoning Tutor: an Intelligent Tutoring System for Visual Reasoning in Engineering & Architecture

*Visual reasoning is an essential skill for many disciplines in engineering, architecture, and design. The underlying cognitive processes of visual reasoning form a basis in various problem-solving processes. We describe an intelligent tutoring system for visual reasoning that uses the missing view problem. This system, called Intelligent Visual Reasoning Tutor (IVRT), can adaptively support different learners' needs, track learners' progress, and provide active critiquing. IVRT uses a two-level reasoning architecture, combining geometric reasoning and semantic technologies, which enables the development of ITS for 3D geometry domains. We discuss IVRT's system architecture and implementation, which includes a learning contents model based on skills, lessons, and problems, and a learner model that measures domain competence as a set of skills. Learning contents and pedagogical teaching strategy rules are stored in standard OWL ontologies, which can be customized by the teacher.*

**Keywords:** visual reasoning; missing view problem; geometric reasoning; semantic technologies for learning; intelligent tutoring systems

**H-P. Yueh and H-J. Sheen**

712–722 Developing Experiential Learning with a Cohort-blended Laboratory Training in Nano-bio Engineering Education

*The rationale and design of this cohort laboratory training, which blends both real NBTL and virtual NBTL, are considered for their effect on student learning. After implementation of the program into a graduate engineering laboratory course, an evaluation study was conducted to investigate the effectiveness of this blended laboratory training program. According to results, most students showed positive attitudes toward this practice. In addition, students perceived positive impacts of this effort on their laboratory learning experience. Furthermore, this paper discusses the important issues observed in the study, such as interdisciplinary learning and teaching. It is expected that this study will contribute to the practice of innovative adoption of technology in engineering laboratory education and research on cyber learning.*

**Keywords:** cohort blended laboratory model; digital learning contents; experiential learning; evaluation, laboratory training

**W-F. Chen**

723–728 Teaching Problem Solving in Engineering Education: Expert Systems Construction

*This study presents a pedagogical model of constructing an expert system knowledge base for an undergraduate computer networking class. This model included: identifying a suitable problem, defining the problem domain, specifying goals or solutions, specifying problem attributes and values, generating rules and examples, and selecting the right tool. In addition, the effectiveness of this problem-based learning approach was verified by an experimental study. Results indicated that students in a student-created expert system group achieved significantly higher scores than a system-provided expert system group ( $F = 5.042$ ,  $p < .05$ ) when they were solving story problems. Creating such an authentic learning environment by asking students to develop their own knowledge base is the main theme of the study. The same instructional technology can be applied to other disciplines that focus on teaching engineering problem solving.*

**Keywords:** expert systems; problem solving; experimental design; computer networking; learning assessment

**M. Rippel, D. Schaefer, F. Mistree and J. H. Panchal**

729–744 Fostering Collaborative Learning and Mass-Customization of Education in a Graduate Engineering Design Course

*The rapid progress of globalization has led to many unprecedented changes in the world in which our students will practice. New product development paradigms such as mass collaboration are redefining the way in which products are realized. The authors believe that in the light of these changes, new approaches to educating the next generation of engineers are needed. Towards this goal, the authors present a pedagogical approach to allow students to experience mass collaboration and to improve their understanding of emerging trends in product development. The approach is designed to foster collective learning and to apply mass customization in education. It is presented in the context of a graduate engineering design course—'Designing Open Engineering Systems'. Two of the main features of the approach are: (1) providing the students with the opportunity to define their own learning goals, and (2) posing a broad question to which the students are required to develop an answer by the end of the semester. All activities of the course are geared towards answering this question—both individually and collectively. Collective learning is facilitated through semester-long continuous development of a collaborative answer to the Q4S by the entire class. Mass customization of education is achieved by having students define their personal semester goals as well as personalizing their answer to the Q4S. A web-based collaborative learning framework is developed for this course using social networking tools to facilitate communication, and to simulate a mass collaborative environment. The authors believe that such pedagogical approaches are essential for developing a foundation for next generation educational environments.*

**Keywords:** mass collaboration; collective learning; educational mass customization; engineering design; question for the semester; social networking

**N. Baloian and W. Luther**

745–754 Cooperative Visualization of Cryptographic Protocols Using Concept Keyboards

*Software called CoBo (Cooperative exploring and visualizing cryptographic protocols using concept keyboards), applies the principle of the "concept keyboard" to implement a system that supports the learning of cryptographic protocols. In previous research, concept keyboards (CK) were successfully used to implement a software system supporting the learning of classical algorithms, like QuickSort and Dijkstra's algorithm, among others. Traditional visualization software normally offers the learner an animated representation of the algorithm with the possibility of controlling the execution of the right steps, giving the learner a more or less passive role. Concept keyboards allow the learner to control the execution of the algorithm by deciding which function should be performed when. Four*

cryptographic protocols were implemented and tested (Wide Mouth Frog, Feige-Fiat-Shamir, Needham-Schroeder and Kerberos V). An initial evaluation confirmed that the use of the CK fosters comprehension of the algorithms, facilitates the learning process and stimulates the learners' activity.

**Keywords:** concept keyboards; cooperative visualization; algorithm learning; cryptographic protocols

**D. Tappan** 755–762 ShelbySim: a Transparent, Pedagogy-oriented Simulator for Computer-based Systems

*ShelbySim is a student-friendly, pedagogy-oriented, open-source software system for designing, simulating, and evaluating a wide range of multidisciplinary, computer-based engineering applications. It consists of three top-level, seamlessly integrated and richly expressive components that focus on software, hardware, and a holistic combination of the two in realistic operational contexts. The software component consists of a Java-like object-oriented programming language, Shelby, a full-fledged, transparent compiler with extensive tracing, logging, and inspection capabilities, and a runtime system for executing its programs. The hardware component is for designing and implementing conceptualized representations of embedded systems and computer architectures that support the software. The simulation component provides a flexible, interactive framework for running controlled experiments on the software and hardware. It provides students with raw data for quantitative performance analysis, evaluation, and reporting of their designs. ShelbySim also functions as an appealing tool for demonstrations and recruitment.*

**Keywords:** software and hardware simulation; design and analysis environment; compilers; embedded systems

**P. Kosec, M. Debevc and A. Holzinger** 763–771 Towards Equal Opportunities in Computer Engineering Education: Design, Development and Evaluation of Video-based e-Lectures

*Innovative instructional technologies not only improve standard, classical learning methods for users but also provide learner centered educational tools that make it possible for people with special needs to benefit from the same courses as learners without disabilities. This paper describes some of the current systems that are available and details a closer study made of one of those: the Video-based e-Lectures for All Participants (VeLAP) system. The study was carried out during sample lectures in engineering using N = 75 students (16 women and 59 men) from technology oriented faculties. The results were evaluated according to their pedagogical effectiveness, including analysis of covariance (ANCOVA) comparison tests. Whilst the emphasis was placed on the applicability of the educational methods for assisting the needs of a special target group, people with audio and/or visual disabilities, the usability of the system for all users, including the teaching staff, was tested according to the standardized Software Usability Measurement Inventory (SUMI). Our findings indicated areas of possible improvement and highlighted the web controls that required adjustments to make the system more usable.*

**Keywords:** web-based education; video streaming technology; people with special needs; evaluation

**M. Ashoori, Z. Shen, C. Miao and L. Peyton** 772–776 Pedagogical Agents for Personalized Multi-user Virtual Environments

*Personalization is a key issue in adaptive virtual learning environments, which support interactive-engagement methods for learners. Recently there has been much progress on advanced graphical interfaces, but more progress is needed to fine tune and adapt such interfaces to end-user's abilities and preferences. One of the emerging challenges in such an adaptive multi-user virtual environment (MUVE) is the development of personalized services such as personalized content management, user-models, or adaptive instant interaction. This paper uses agent technology as an effective framework for developing personalized services in a MUVE. The proposed framework is validated by applying it to Virtual Singapore (VS), an agent augmented virtual environment designed to engage and motivate learners at the lower secondary level in Singapore as they learn important scientific knowledge and skills.*

**Keywords:** personalization; pedagogical agents; multi-user virtual environments; Dempster–Shafer belief accumulation; user model

## Part II

# Contributions in: Active learning, Design-based learning, Computer Engineering, Electrical Engineering, Robotics, and Mechanical Engineering

**J. Marcos-Acevedo, S. Pérez-López, J. Sánchez-Real, R. Alvarez-Santos and M. Suárez Álvarez** 777–787 Active Learning Approach for Engineering in Collaboration with the Corporate World

*This paper presents the work carried out in the Department of Electronic Technology (University of Vigo) during the ten-year life of 'Electronic System Reliability', a subject that is included in the final year of the Telecommunication Engineering degree (Electronics speciality). We explain the approach adopted, which in addition to using traditional methods adds a new framework that involves industry to improve the students' rate of learning. Local companies play a key role by actively collaborating in the process. The knowledge obtained by the students for developing part of their training within the company gives them an experience that would otherwise be impossible to achieve in the classroom alone. On the other hand, the company acquires contributions from the students on issues related to Dependability, something to which the technicians can never devote enough time. Furthermore, the students often bring to the company another point of view, which can be interesting, in looking at a given issue. The results achieved show this methodology to be very interesting for engineering studies, particularly in the final year disciplines as long as there is an industrial environment that is willing to collaborate.*

**Keywords:** dependability; reliability; availability; maintainability; safety; education; electronics; EHEA

**B. Reynolds, M. M. Mehalik, M. R. Lovell and C. D. Schunn** 788–798 Increasing Student Awareness of and Interest in Engineering as a Career Option through Design-Based Learning

*This paper describes a rigorous summer research experience and curriculum development opportunity for teachers, supported by professional development and classroom support, culminating with a citywide student design competition. The goal of this Research Experience for Teachers program was to bring real world innovative design into several urban, high school classrooms. The 8-week summer program comprised an engineering component and a learning science component. The goal of the engineering component was to provide an authentic research experience. Teams of 2–3 teachers were paired with a researcher in a school of engineering to further ongoing research of a product realization project. The goal of the learning science component was to scaffold teachers to develop a design-based immersion unit that they would implement in their science classrooms. Teams were organized by their content areas and provided professional development at a learning research center around relevant curriculum development strategies. This paper presents results related to common sets of knowledge and skills that teachers learned from both engineering design and learning science from the cohorts of teachers over the last three years. Findings include documentation of implementation success, changes of teachers' and students' beliefs about engineering and increases in student interest in engineering careers.*

**Keywords:** engineering pipeline; teacher professional development; design-based learning

*The aim of this paper is to develop and implement a progressive project to evaluate the current teaching/learning process in our universities. We will also consider the fact that in order to measure and certify the acquisition of cross curricular competencies, such as being able to search for specific information, working in a group, etc., we will have to identify the roles and responsibilities of the teaching professional in the team involved in the courses: Subject Head, Student Body Tutor, Project Co-ordinator and Head of the Centre's teaching plan. We also include a sample of the teaching/learning process divided into four phases: Reflection, Active methodologies plan, Execution and Assessment. Next, we describe the application of this approach inside the current Engineering Degree curriculum in the Vilanova i la Geltrú's Higher School of Engineering (Technical University of Catalonia). We will include examples of the use of PBL (Problem-Project-Based Learning) and Cooperative Learning in subjects in the MSc Engineering curricula Automation and Industrial Electronics Engineering in two High Schools at the Technical University of Catalonia (UPC). Through these experiences we will illustrate the conjoining and coordinating of subjects and how the competencies of our students are measured in order to make academic changes much easier and, therefore, give us more confidence in facing the imminent European Higher Education convergence.*

**Keywords:** active methodologies; problem-based learning; project-based learning; teaching quality

*The (semi-)automated management of programming assignments promises efficiency in large classes and fairness for the students. This paper presents an approach and the relative supporting environment for automated assessment of programming assignments that was developed for an object-oriented programming course. The user interface of the tool is tightly integrated into the Eclipse development environment, which is used by students in the labs. The assessment and grading are based on automated tests that allow an objective evaluation of the working features delivered by the students. The grading is based on the number of test cases passed, and on the distance, measured in lines of code, between the program developed in the lab and a corrected, fully functional version of it. This two-phased approach allows achieving a quantitative evaluation of the defects and of the missing functions.*

**Keywords:** laboratory-based teaching; automated learning systems; teaching/learning strategies; programming and programming languages; object-oriented programming; Java programming

*In this paper the use of an open mobile robot platform as an innovative educational tool to promote and integrate different interdisciplinary curriculum knowledge is presented. In addition the program and acquired experience of a summer course named 'Applied Mobile Robotics' is outlined. The main aim of the course is to integrate different subjects such as electronics, programming, architecture, perception systems, communications, control and trajectory planning by using the educational open mobile robot platform PRIM. The summer course is offered to Electrical and Computer Engineering students at around the time of their final academic year. As a practical approach, most of the educational activities of the course are developed in our university labs. The students are greatly motivated by working on such a robotic platform, which allows them to consolidate their previously acquired knowledge and to extend their complementary curricula. To achieve this, the resolution of real-world approaches is used to increase the students' understanding of fundamental engineering concepts within an interdisciplinary methodology context. Moreover, realistic platforms that incorporate engineering standards and realistic constraints increase student skills and experience through engineering practices.*

**Keywords:** robotics; electrical and computer engineering; interdisciplinary knowledge; control and mechatronics; educational applied programs

*In this paper, the development of a physical platform and the description of a specific methodology to be employed for experimental teaching in wind energy electrical generation in the 'Electrical Generation with Renewable Energy Sources' course, within the Electrical Engineering educational program at the Universidad Politecnica de Madrid, is presented. The developed platform has a reduced-size wind turbine to which some different types of scaled-size electrical generation systems can be coupled. The instructors can easily configure the specific structure of this platform for each laboratory session. A regulated electric fan is employed to generate and control the speed of the wind that is incident on the wind rotor. Students can configure the session specifications and are able to control the execution of each experiment, as well as to analyze the results in a comfortable way using user-friendly interface software. This paper also describes, as a case study, the application of the proposed methodology in one of the laboratory sessions.*

**Keywords:** electrical engineering education; electric machines; wind energy

*The bending problem of Euler–Bernoulli discontinuous beams is a classic topic in mechanics. In this paper stepped beams with internal springs are addressed based on the theory of generalized functions. It is shown that in this context a closed-form expression may be given to the Green's functions due to point forces and, based on these, to the beam response to arbitrary loads, for any set of boundary conditions. The proposed solution method may be presented in a regular course in Mechanics of Solids and Strength of Materials for undergraduate students. It does not require an advanced knowledge of the theory of generalized functions but the knowledge of only a few basic concepts, most of which are generally presented in other courses such as, for instance, Dynamics of Structures. It is hoped that it may help students to address in a simple and effective way the many engineering applications involving discontinuous beams.*

**Keywords:** static Green's functions; Euler–Bernoulli beam theory; discontinuous beams; flexural-stiffness steps; internal springs