

# The International Journal of Engineering Education

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#### Special Issue: Methods and Cases in Computing Education

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In recent years many universities worldwide are promoting social-based education models. The Service-Learning pedagogical methodology has been adopted to do that. In computer science education, the Socially Relevant Computing paradigm is gaining inertia. Many discipline-based service-learning approaches in engineering education are focused from the technology-based perspective. That means, the way needs should be fulfilled is through technology conceived and developed perhaps without any societal context. In this paper we propose going beyond this traditional conception. We present a methodology tested for three years on how to teach the design of Socially Relevant Computing Systems for social change. By taking into account a social-based design methodology, named Social Intelligence Design, and a multidisciplinary approach, students from computer-related academic programs can design the social change and see the technology as a mean to accomplish that. Examples of some Socially Relevant Computing systems for social change are provided. We validate our proposed methodology with a questionnaire based on the ABET outcomes. The proposed approach seems very promising to design and conceive Socially Relevant Computing systems within this new paradigm.

**Keywords:** socially relevant computing; service-learning; computing education; multidisciplinary course; social intelligence design; social change

<b>Camino Fernández, David Díez, Telmo Zarronandía and Jorge Torres</b>	14–23	A Student-Centered Introductory Programming Course: The Cost of Applying Bologna Principles to Computer Engineering Education
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The Declaration of Bologna proclaims to change both the academic organization and the way of teaching that are currently implemented in European Higher Education. With regard to teaching methods, an instructional strategy focused on lecturers' teaching is being replaced by methodologies focused on students' learning. However, the application of a student-centered instructional strategy, known as 'active learning', is a formidable task, requiring a great deal of effort from all those involved, plus a suitable instructional process and a set of specific instructional activities. This paper shows the pilot case study of an introductory programming course of the degree in Computer Engineering based on an active learning strategy. Such a pilot case study was carried out to analyze the outcomes of applying the Bologna principles and, based upon those outcomes, to identify the needs and distinctiveness of the Declaration as well as the methodological changes required to implement such principles. During a whole semester, learners followed a continuous assessment process and a student centered instructional strategy that involved an extra effort from both students and teachers. The results show learners benefited from the experience but the system is not entirely prepared to support the new instructional process and several adaptations should be made. Throughout this paper, in addition to the explanation of the pilot study, a set of recommendations, instructional principles, educational tools, and methodological directions will be outlined in order to provide a discussion framework that stimulates and focuses the debate on the application of the Bologna principles to the learning programming activity.

**Keywords:** Bologna Process; computer education; programming course; pilot study

<b>Elena García-Barriocanal, Salvador Sánchez-Alonso and Daniel Rodríguez-García</b>	24–30	Devising Instruction from Empirical Findings on Student Errors: A Case in Usability Engineering Education
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Problem-based learning relies on the use of problems as the fundamental activity driving the learning process, focusing on the application of knowledge to realistic settings. Problems requiring students the design or evaluation of artifacts are a fundamental ingredient of engineering education in diverse fields. In those settings, the effectiveness of instructional design critically relies on the quality of the problems used, which should emphasize the aspects that students usually find difficult to master, so that relevant domain knowledge is exercised during learning activity. The analysis of the errors in student's solutions to problem assignments can be used as an empirical source of information for the instructional design of problem collections. In this approach, problem design is driven by findings on the kind and frequency of errors. This paper reports the use of such an approach in the domain of heuristic usability evaluation in the context of an introductory Human Computer Interaction course, using the 3C3R model as a framework. The method for data elaboration and the resulting approach to devising problems can be transferred to other domains in which similar high-level design analysis is required.

**Keywords:** usability engineering; heuristic evaluation; student assignments; problem-based learning; evidence-based education; 3C3R model

The idea of using CASE (Computer Aided Software Engineering) tools in education as an interactive learning has been emerging for several topics in Computer Science. The learning process proves to be more effective, rapid and even persistent. This paper presents a CASE tool named Software Engineering Tutor (SET), which main aim is to improve the students' knowledge in Software Engineering field, specifically to guide them in the creation of domain and use case models. Besides, this tool offers a repository of case studies, trying to make an effort to share experiences around the university and professional community. Our experience with this tool during the 2008-2009 academic year, in an introductory Software Engineering course, shows that SET is a useful tool for teachers, in their learning approach, and very instructive in the assimilation of knowledge for students. Moreover, it has become a key element for the continuous assessment process support that was introduced in 2005-06 course.

**Keywords:** Software Engineering Tutor; CASE tool; interactive learning; problem-based learning; continuous assessment; case study; computer science education

Software engineering education faces increasing pressure to provide students with those skills required to solve different kinds of software problems both, alone or as a member of a development team. Consequently, one of the main goals of software engineering curriculum is to teach students how to model, design and implement software, as well as how to exploit previous successful experiences and knowledge of others in solving similar problems. These are inherently practical skills and rely on functioning knowledge. To facilitate a learning environment in which students can acquire a necessary level of understanding, it is necessary to apply an active learning paradigm, which recognizes that student activity is critical to the learning process. In this paper, we propose a project-based collaborative learning environment for learning software design patterns that integrates several existing educational systems and tools based on the common ontological foundation. The learning process in the suggested environment is further facilitated and augmented by several context-aware educational services. Our first evaluation demonstrated some promising results for effective teaching and learning of design patterns.

**Keywords:** semantic web; ontologies; collaborative learning; project-based learning; software patterns; context-awareness

Virtual Worlds have become a very popular kind of software application that has been used in different fields, from games to simulation or education. They allow individuals to interact with others through their avatars and with objects in the environment. Virtual Worlds provide new educational experiences where collaboration and cooperation among users can be easily achieved. This paper presents the results of an experience in which students from several high schools were offered a course on programming through a VW educational platform in order to make programming concepts more appealing. At the same time the proposed platform minimizes the effort required by the teachers to use the VW environment. The paper analyses the didactical issues of the created virtual world and the main problems that have been solved in order to develop the operative educational platform. Finally, an evaluation of the subjective experience of students and teachers when using the WV environment was carried out. The results of this evaluation show that both teachers and students had a very satisfactory educational experience.

**Keywords:** Virtual Worlds; OpenSim, Second Life; Educational Experiences; Programming Courses; Virtual Education, V-Teaching

ACME-DB is a web-based e-learning platform designed for giving support to the teaching and learning of main database course topics. The platform is composed of a set of correction modules capable of automatically correcting different types of database problems such as entity-relationship diagrams, relational database schemas, normalization, relational algebra and SQL. The capabilities of ACME-DB provide us with a powerful tool for skills training and automatic assessment of main database course topics. In this paper we describe how ACME-DB has been used in different database courses at our university and how it has influenced academic results in a positive manner.

**Keywords:** database design; e-learning; web-based tools

The exponential increasing in software size and complexity is miring testers with endless testing work and assuring software quality becomes more difficult. A pedagogical model was proposed for SQA at source code level, in which coding standards and code optimization were determined as two quality buses while code review traversed almost the entire software development process. In order to consolidate this model, some topics were researched such as evaluation index system of coding standards, evaluating website of coding standards, process improvement and behavior analysis of peer code review, and so on. The model was developed over four academic years of practice; it is possible for students to eliminate defects in their programs at source code level.

**Keywords:** software engineering education; software quality assurance (SQA); source code level; coding standards; peer code review (PCR)

## Part II

# Contributions in: Engineering Education Research, Information Management, Teaching Engineering Design, Learning Models, Problem-based Learning, Distance Learning, Instructional Development, Control Systems, and Power Electronics

Engineering education research in many countries and regions is gaining momentum and coherence as a field of academic activity. Yet what quantity and kinds of research are currently being done, both worldwide and in specific nations and regions? Additionally, what collaborative patterns are now evident in the field, including in terms of the size and multi-national composition of research teams? To address these research questions, we first review previous attempts to quantify and characterize research on engineering education and related fields. We then use theoretical and methodological insights from social studies of science,

bibliometrics, and scientometrics to perform quantitative and qualitative analysis of 2,173 journal articles and conference papers published 2005 to 2008. Our findings are presented in five main parts. First, we describe how basic criteria were used to identify 885 empirical research papers and track changes in the orientation of the major publication outlets in the field. Second, analysis of author affiliation information allows us to report on publication activity by country and region. Third, we discuss evidence of collaborative patterns, including co-authorship trends and prevalence of multinational research teams. Fourth, we examine keywords in article metadata to report on the prevalence of 38 categories representing different research topics and contexts. Fifth and finally, we examine co-occurrence of articles by category. The paper concludes with recommendations for building global capacity in engineering education research, including suggestions for expanding cross-national collaboration in targeted research areas and improving access to the field's literature.

**Keywords:** bibliometrics; collaborative research; empirical research; engineering education research; global; international; ontology; scientometrics

**Ming-Hua Chang and Chi Cheng Chang** 91–100 Developmental Model of Strategic Alliance for Technological Education

Based on the value chain model of competition strategy theory, this paper explores the existing strategic alliances for technological education in Taiwan and uses the field of information management as an example to build a multiple developmental model for inter-school strategic alliances. The research methods include panel discussions and surveys. The paper can be divided into three major parts: Part one describes the status quo of strategic alliances for technological education in Taiwan; Part Two introduces a multiple developmental model formed by the teachers' professional development; Part Three uses an empirical investigation of schools of different levels to demonstrate the effects of the above-mentioned multiple developmental model. The contribution of such a developmental model lies in the construction of a cooperation value chain and the high efficacy of generating values for both teachers and students.

**Keywords:** strategic alliance; technological education; information management; model

**R. F. Hamade and N. Ghaddar** 101–113 Impact of Team Functions in an Introductory Design Course on Student Performance in Later Design Courses: A Longitudinal Study

In ME Tools, an introductory undergraduate mechanical engineering course, students work in teams, acquiring design and process development knowledge. Throughout the course, each student assumes one of four possible roles: manager, systems engineer, analyst, or details designer. Team function assignments are based on student response to a short questionnaire. This paper reports on the findings of a longitudinal study that tracked the performance of 204 students as they progressed through the design curriculum up to and including the final year project course. Tracking is achieved using repeated measures ANOVA (RMANOVA). Interactions between the introductory course grades and sub-grades of the major deliverables (report and contest) and those from the other design courses were statistically examined after being divided according to team function. The strengths of these interactions (p values) are reported, with the impact of team functions on performance in the design courses taken by the students often being shown up to three years later in their curriculum. It was also found that 64% of all teams formed for the capstone project contained two or more members of the team originally formed in ME Tools.

**Keywords:** mechanical engineering; design; process development

**David C. Shallcross, Gavin Buskes and Raymond R. Dagastine** 114–127 Teaching First Year Engineering Design and Design Criteria—The Thames Barrier

The Thames Barrier is an iconic engineering structure protecting London from dangerous storm surges that might otherwise flood the city. Built in the 1970s, engineers considered many different designs before settling on the final one featuring six rising sector gates and four falling radial gates. The design of the Barrier and the many different design iterations that the engineers went through in response to the changing requirements of the client provide an excellent context within which to teach first year general engineering students design and design criteria in an introductory context. The design process of the Thames Barrier has been used as a case study in a general first year engineering subject at the University of Melbourne for several years. This paper describes several of the original designs proposed to close the Thames before the final design was developed. A detailed description of the Thames Barrier as built is given before the application of the case study to the classroom is discussed. An analysis of 226 concept maps prepared by the class 10 weeks after the material was delivered provides an insight into how the students integrated and retained the material from the case study.

**Keywords:** engineering education; design; first year; Thames Barrier; concept mapping

**Chris Poyner, Mary Court, Huong Pham and Jennifer Pittman** 128–137 A 3-D Pyramid/Prism Taxonomy for Viewing Knowledge When Teaching Language-Focused, Undergraduate Simulation Courses

We developed a 3-D knowledge pyramid/prism model to structure the relationships of lower-level learning, 'optional' knowledge bases, concurrent knowledge, and new knowledge; so we may view learning needs of a higher-level learning objective. Our paradigm stems from Bloom's taxonomy, but has the advantage of supporting 'just-in-time' and 'learn-by-doing' delivery, teaching and learning styles. We illustrate the paradigm through the BMMKP (3-D knowledge pyramid/prism model of the highest-level, batch-means-method learning objective for our language-focused, undergraduate course). The BMMKP reveals how highly dependent and fully integrated this learning is to calculus, probability, statistics, and queuing theory—regardless of the simulation modeling language chosen. The BMMKP is then used to develop a set of lower-level learning objectives for the undergraduate course. The 3-D pyramid/prism approach should lend itself well as a communication tool for visualizing other simulation learning objectives.

**Keywords:** learning models, just-in-time learning, concurrent learning

**L. Pérez Urrestarazu, A. Franco Salas and R. Fernández Cañero** 138–145 Multidisciplinary Education for New Landscape Engineering Concepts using Problem-Based Collaborative Learning. A Case Study in Spain

Problem-based learning (PBL) is widely regarded as a successful educational method. In Spain, most engineering degrees are still based mainly on old style lecture classes where a great deal of information is given to the students. This work assesses the introduction of a PBL strategy as a complement to traditional engineering education. The instructors' and students' attitudes towards its implementation are studied. A new approach has been proposed for the PBL strategy: instead of a single problem, a chain of problems was developed that could be solved in a collaborative environment. Results from the experience showed a high level of student acceptance. Response to the PBL initiative was found to be positive both for instructors and students, though lack of time, difficulties in evaluations and an increase in students' and teachers' workloads were the main disadvantages. Compared with traditional engineering curricula, the mixed traditional-PBL model appears to inspire a higher degree of involvement in study activities where on-line learning tools played an important role.

**Keywords:** PBL; collaborative learning; multidisciplinary education

**Julio Ariel Romero** 146–154 Problem-Based Learning in an Industrial Computers Course

In this paper we present the steps taken to introduce PBL into the Industrial Computers course in Computer Engineering education. Our goal was to supplement the methodology based on a combination of theoretical lessons and laboratory experiences by solving a specific technical problem. To achieve this, we applied a pedagogical model that incorporates theoretical lessons, laboratory experiences and Problem-Based Learning (PBL). The scheme presented in this paper is designed to minimize disturbances due to the introduction of PBL. The most important issues in the proposed pedagogical model are covered in this

paper, such as: the features of the proposed problem that really drive student learning; the method used to supervise student learning and the scheduled evaluations made during the course. The proposed model has been applied since 2006. The results of a survey completed by the students in academic years 2006/07, 2007/08 and 2008/09 are presented. The objective of the survey was to verify the advantages of the proposed pedagogical model. The results of both the survey and the students' evaluations indicate that the objectives were met and, at the same time, students were highly satisfied with the knowledge they had acquired during the course.

**Keywords:** problem-based-learning; industrial computer

**Suzana Markovic, Nenad Jovanovic and Ranko Popovic** 155–166 Web-Based Distance Learning System with Adaptive Testing Module

User models are essential to e-learning systems, giving students learning continuity, tutors the evidence of students' progress, and both a way to personalize students' learning materials according to their abilities and preferences. Personalizing information has long been the motivation behind developing e-learning systems. Adaptive educational systems attempt to maintain a learning style profile for each student and use this profile to adapt the presentation and navigation of instructional content to each student. This kind of system adapts the learning process on the basis of the student's learning preferences, knowledge, and availability. One such Web-based tool is built at the Business School of Professional Studies in Blace (the system of intelligent evaluation using tests), which infers student knowledge using adaptive testing. The knowledge will not be evaluated according to fixed standards, but it will depend on individual characteristics of each student. This system will enable the aforementioned school to modernize education.

**Keywords:** student profile; adaptive system; adaptive testing; learning style

**Ning Fang** 167–177 A New Methodology for Assisting the Development of Instructional Awareness in Teaching a Large Engineering Class with Academically Diverse Students

Instructional awareness is an instructor's clear and comprehensive understanding of his/her teaching pedagogy and practice. It affects teaching effectiveness and ultimately student learning. This paper presents a statistics-based, quantitative, and objective methodology to help develop instructional awareness in teaching a large engineering class with academically diverse students. The new methodology consists of three steps: collect data on student classwork and exam performance, identify student academic performance groups, and conduct paired-sample t-tests on each student group. A case study, which involved 236 undergraduate engineering students in three semesters, is provided to demonstrate how the methodology can be employed step by step. The results show that the methodology is valid to reveal whether or not an instructor's instructional strategies are more beneficial to one student group than another.

**Keywords:** instructional awareness; student academic performance groups; paired-sample t-tests; instructional strategies

**M. L. Pertegal-Felices, A. Jimeno-Morenilla and J. L. Sanchez-Romero** 178–186 Use of Discussion Boards as a Student-Centered Methodology for Large Groups in Higher Education

A major problem encountered in higher education today is the high university dropout or failure rate of students coming from secondary education. Most of them drop out in the first year of their studies, primarily because at this initial stage they are affected by the high impact of university teaching after the experience of the high school educational system. This work analyzes the causes of this impact on one of the subjects that has high failure rates in Computer Engineering studies. The idea presented moves beyond the simple implementation of a discussion board to the development of a methodology for including discussion boards in a course. The method uses discussion boards as a complementary tool for learning and evaluation. It is especially useful for large groups. The methodology was put into practice during the 2007/2008 and 2008/2009 academic years, obtaining good results without loss of quality of the contents addressed in the subject.

**Keywords:** failures in higher education; student-centered methodology; collaborative learning; problem-based learning; group work; large group teaching; discussion boards

**Liliana Fernández-Samacá and José Miguel Ramírez** 187–199 Learning Control Concepts in a Fun Way

This paper proposes Hands-On sessions as a didactic strategy for lectures in theoretical courses, where students can construct and understand control concepts when they play a game designed by the teacher. The teacher uses a game to introduce the topic in order to motivate the students to learn in a fun way and improve their knowledge retention. Students develop activities in groups of three to five members; they follow instructions from a guideline describing the game. Hands-On sessions offer an alternative to learning control theory from concrete experiences so students can grasp knowledge and relate the concepts to simple events. The game can be seen as a road to achieving concepts; it has key issues that allow students to construct knowledge. This approach proposes employing Hands-On sessions using simple materials instead of high-technology complex elements, software, or a specialized space. This work describes a model to design and develop Hands-On sessions. It also introduces activities designed for students to learn topics such as: describing a typical control loop, analysis in the time domain, stability, root locus analysis, and frequency analysis, for control courses in an engineering program. Finally, the paper describes feedback and comments from the students.

**Keywords:** Hands-On sessions; control education

**A. Ndtoungou, AB. Hamadi and K. Al-Haddad** 200–213 An Improved Approach to Better Understand Power Electronics Variables

This paper aims to improve the teaching methodology for self-learning for teachers and students working in the area of power electronics. Three different methods have been proposed, mainly using mathematical equations, MATLAB/Simulink and MATLAB functions. This paper also proposes an easy way of calculating the exact values of the extinction angle known as 'beta'. This avoids the use of the monogram known as the 'Puchlowsky monogram'. In this paper the exact calculation of the rms load current for a single-phase controlled rectifier with R-L load is given. A three-phase controlled rectifier with a highly inductive load is also discussed in this paper with an interactive variable load resistance and inductance. The simulation results have been presented and extensive simulation and experimental studies have been carried out to analyze different waveforms under varying load conditions.

**Keywords:** education; power electronics; MATLAB; extinction angle; integration limits