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Section I

Special Issue

Learning through Play in Engineering Education—Part 1

Guest Editor

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Ahmad Ibrahim	479	Editorial
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Wei-Fan Chen, Weh-Hsiung Wu, Tsung-Yen Chuang and Pao-Nan Chou	482–487	The Effect of Varied Game-Based Learning Systems in Engineering Education: An Experimental Study

This study developed and evaluated two varied game-based learning systems in a software engineering class. The first system adopted a role-playing gaming strategy for students to learn about the process of software development effort estimation in a team-based environment. They played different characters, such as a project leader, a system analyst, a system designer, or a programmer. The second system used a traditional drill-and-practice gaming strategy to guide design. An experimental study involving human subjects was conducted to compare the effects of both systems on students' learning performance and attitude. Univariate analyses revealed that the game-based learning had a significant main effect on dependent variables in the knowledge test ($F = 5.166$, $p < 0.05$), but not in the intention and satisfaction measures ($p > 0.05$). The results showed that students in the drill-and-practice gaming group achieved significantly higher scores in the knowledge test ($M = 72.86$) than the role-playing gaming group ($M = 61.90$). The measures of students' intention and satisfaction were in the range of a moderate to high level. However, no significant differences were found between the two groups about their affective measures: (1) intention to use gaming platforms ($F = 0.016$, $p > 0.05$) and (2) satisfaction toward the assigned gaming platforms ($F = 1.854$, $p > 0.05$). The effect of students' motivational factors in both gaming groups was about the same.

Keywords: game-based learning; software engineering education; quantitative evaluation; experimental study

Andrés Díaz Lantada, Pilar Lafont Morgado, Juan Manuel Muñoz-Guijosa, Javier Echávarri Otero and José Luis Muñoz Sanz	488–497	Learning Through Play in a Final Year Subject: Enjoyable Design Experience for Teaching Product Development
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In recent years educational gaming has been progressively perceived as a very effective tool for improving teaching-learning activities in higher education. The use of such play-based methodologies for engineering education can promote several practical and communication skills of great value for students' future professional development. At the same time it greatly helps to motivate students and make them more aware of their own capabilities and the learning process.

This paper details the application of a play-based methodology for improving students' results and motivation in the subject 'Development of Plastic Products'. The active learning strategy consists in assigning student groups different toy development tasks, so that they can apply the design concepts learned and present their results in public. It is thereby hoped to promote a set of abilities that are ever increasingly valued in the industrial and business world, such as teamwork, creativity and communications skills.

Results have been compared with experiences from previous years, linked to the development of conventional products. The results show that carrying out a monographic experience on 'Toy—Design' has promoted students' satisfaction, motivation and results. Some ideas for future improvements, mainly based on students' opinions, are also discussed.

Keywords: learning through play; active learning; motivating students; CAD-CAM-CAE tools; rapid prototyping technologies

Miroslav Minović, Miloš Milovanović, Ivana Kovačević, Jelena Minović and Dušan Starčević	498–508	Game Design as a Learning Tool for the Course of Computer Networks
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Continuous advances in technology are causing a generation gap between students and teachers to increase. There are constant breaks in communication, misunderstandings and social conflicts arising during the conduct of a course. Today students have grown up using devices like computers, mobile phones, and video consoles for almost any activity; from studies and work to entertainment or communication. Motivating them with traditional teaching methods such as lectures and written materials is proving to be more difficult daily. In order to increase the motivation of students, better understanding of the subject matter as well as improving collaboration, new form of teaching was required. That is why digital games are being considered to have a promising role in education process. We conducted a study among university students with the purpose of acquiring empirical evidence to support the claim that game design can be used as an effective form of learning. Our method consisted out of monitoring results of participants in course of Computer networks. Experimental group of participants experienced a game design as a new learning tool for teaching, while control group used network programming. Additionally, we invested an effort to measure the effects of different learning approaches with the respect of individual differences in cognitive styles. Initial results provide a good argument for use of game design as a student learning tool. In addition, we reported some influence of cognitive style on effectiveness of using game design.

Keywords: learning tool; game design; educational game; cognitive style

Joaquín Olivares, Jose M. Palomares, José Manuel Soto and Juan Carlos Gámez, Ignacio Bravo and Aldredo Gardel	509–517	Learning FPGA Design by a Methodology Based on Projects
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In the Digital Electronic Systems subject of the Engineering Degree in Automatics and Electronics, a methodology based on projects has been proposed according to the Bologna agreement. The purpose of these works is to implement digital systems in FPGA technology, most of them are based on games. With their projects, students prove their subject knowledge. Furthermore, this activity is used to introduce cross activities in the scope of the whole degree and make relationships with contents of other subjects. This paper describes the learning methodology and assessment. Results are compared with the previous methodology

based on exams. Furthermore, a remote laboratory that permits open access from home is presented. Collaboration between two universities has been proposed, respective remote labs can be used by all the students, in such a way, that interuniversity cross activities are to be introduced.

Keywords: remote laboratory; Project Based Learning (PBL); teaching experiences

Vicenc Fernandez, Pep Simo, Ines Algaba, 518–527 ‘Low-Cost Educational Videos’ for Engineering Students: a new Concept based on Video Streaming and YouTube Channels
Maria Albareda-Sambola, Nuria Salan, Beatriz Amante, Mihaela Enache, Edna R. Bravo, Albert Sune, Daniel Garcia-Almiñana, Manel Rajadell and Federic Garriga

There are many papers that present the problems of educational videos: need of a high number of resources to create them, excess of information in the majority of videos, gaps of information between videos and the rest of materials of the courses, etc. This paper introduces the concept ‘low-cost educational video’, which attempts to solve to a large extent the problems that have been identified in the educational videos. To this end, an empirical research is conducted with 487 students and various lecturers and professors in three undergraduate degrees: Mechanical Engineering, Industrial Engineering and Management (in face-to-face as well as semi-distance modalities), and Aeronautical Engineering at the Universitat Politècnica de Catalunya (Spain). In order to achieve this goal, we introduce the process and the required resources for the creation and the diffusion of these low-cost educational videos. The results are analysed taking a literature-based questionnaire as a starting point and within the principles of good practice in higher education framework. The main research findings revealed an improved student motivation and an increase of the perceived efficiency in the learning and teaching processes, without substantially raising costs.

Keywords: low-cost videos; video streaming; teaching methodologies; student motivation; perceived efficiency

J. Sánchez, S. Dormido-Canto, G. Farías, 528–534 Understanding Automatic Control Concepts by Playing Games
F. Godoy and S. Dormido

This paper presents three simulation-based games developed by the Department of Computer Science and Automatic Control at the Spanish University for Distance Education (UNED) to aid in the teaching/learning process of basic control concepts. The learning subject of the games is a PID controller, which is a control element that is commonly included in the syllabus of an introductory course on automatic control. The games are part of the results of a European Leonardo da Vinci pilot project entitled ‘AutoTECH: Automation Technicians Vocational Training Repository’. The goal of this project is to develop and disseminate innovative software packages for technicians and vocational students in the automation and control field. These training packages will improve the quality of learning of these two groups of people and increase their motivation to acquire new knowledge related to their professional careers. Each of the packages contains both traditional (e.g., theory, exercises, quizzes) and web-based (e.g., interactive simulators, remote operable labs, games) learning resources.

Keywords: control education; learning-by-playing; dynamic simulations; Java

Ana Vazquez Alejos, J. A. Gay Fernandez, 535–549 Innovative Experimental Approach of Learning-Through-Play Theory in Electrical Engineering
Manuel Garcia Sanchez and Iñigo Cuiñas

In this paper we introduce an approach of play-based learning within electrical engineering. The proposed methodology tries to develop a play-based experience by two stages: firstly, the learning by doing theory will teach the ‘rules of the game’ and then, it is completed with a final practice that implements the rhetoric of the learning-through-play theory. Both techniques have resulted in positive learning outcomes by enhancing the student role in the learning process through increasing the motivation.

An experimental play-based Wireless Sensor Network (WSN) platform is introduced as an aid in teaching location techniques based on RSSI (Received Signal Strength Indicator) in the frame of a radiolocation course at graduate level. The platform is implemented using low-cost commercial modules and one easy-to-use software program.

We deepen in the layout challenges facing instructors in the frame of a play-based learning experience. So, we outline critical points as the teacher’s role, the time constraint and the trade-off between actual advantages and efficiency.

We propose also one method to correctly evaluate the cognitive and affective dimensions of the play-based settings by the development of a smart learning route chart that represents a study guidance indicating the flow expected for the objectives and its evaluation.

Keywords: learning through play; learning by doing

Rafik Absi, Caroline Nalpas, Florence 550–558 Teaching Fluid Mechanics for Undergraduate Students in Applied Industrial Biology: from Theory to Atypical Experiments
Dufour, Denis Huet, Rachid Bennacer and Tahar Absi

EBI is a further education establishment which provides education in applied industrial biology at level of MSc engineering degree. Fluid mechanics at EBI was considered by students as difficult who seemed somewhat unmotivated. In order to motivate them, we applied a new play-based pedagogy. Students were asked to draw inspiration from everyday life situations to find applications of fluid mechanics and to do experiments to verify and validate some theoretical results obtained in course. In this paper, we present an innovative teaching/learning pedagogy which includes the concept of learning through play and its implications in fluid mechanics for engineering. Examples of atypical experiments in fluid mechanics made by students are presented. Based on teaching evaluation by students, it is possible to know how students feel the course. The effectiveness of this approach to motivate students is presented through an analysis of students’ teaching assessment. Learning through play proved a great success in fluid mechanics where course evaluations increased substantially. Fluid mechanics has been progressively perceived as interesting, useful, pleasant and easy to assimilate. It is shown that this pedagogy which includes educational gaming presents benefits for students. These experiments seem therefore to be a very effective tool for improving teaching/learning activities in higher education.

Keywords: Atypical experiments; fluid mechanics; teaching assessment; evaluation analysis; semantic analysis; play-based pedagogy; higher education

Beatriz Amante, Maria Martinez-Martinez, 559–570 ‘Applied Scientific Method’ in the Laboratory
Ana Cadenato, Isabel Gallego and Nuria Salan

This paper provides a description of how to incorporate and develop a specific set of applied skills for university science and technology laboratory activities. These skills are what constitute the Applied Scientific Method for problem solving at this field. The application of this method aims to enhance the student learning process in educational laboratory environments. With the objective of facilitating the understanding of these skills, a series of components and elements were outlined. Subsequently, to allow for the systematic integration of each of these components of the Applied Scientific Method throughout the course, four different levels of complexity were established. Three key stages of the learning and skill development process were then incorporated based on the various lab activities carried out; pre-laboratory, in-laboratory and post laboratory. The Applied Scientific Method was applied to the laboratory components of three courses of the Chemical and Industrial Engineering degrees of the UPC-BARCELONATECH (Spain). The first results obtained show a positive reception (pre-lab, in-lab and post-lab) by the student body and, moreover, demonstrate higher standards in the projects presented as post-laboratory assignments.

Keywords: skills; laboratory; scientific method; engineering; science and technology

Iñigo Cuiñas, Verónica Santalla, Ana Vázquez Alejos, María Vera Isasa, Edita de Lorenzo Rodríguez and Manuel García Sanchez 571–579 Playing LEGO Mindstorms® while Learning Remote Sensing

An experience developed in the frame of a graduate level course in Electrical Engineering is introduced in this paper. The use of LEGO Mindstorms indexer and sensors appears to solve the need of cheap and interactive experimental work to learn about sensors along a topic on Remote Sensing, involving the students in a play that becomes a strong learning tool. The evaluation methodology consisted in a test and a survey. The outcomes show a large satisfaction level among students, but also a correct labour in the cognitive dimension.

Keywords: learning through play; affective; cognitive

Nathaniel Lasry and Pierre-Osias Christin 580–584 Engineering Magical Learning Environments

Students enter science classrooms with numerous conceptions, many of which are partial and inaccurate. Misconceptions can be addressed by designing demonstrations that are counter-intuitive to students. Just as magicians use unexpected observations to entertain their audiences, demonstrations become magical when they are designed to breach student expectations in an entertaining and non-threatening way. This paper provides instructors with practical means to convert classical demonstrations into magic tricks. To illustrate the procedure, two classical demonstrations are re-presented as magic tricks that we have used in our college classrooms.

Keywords: magic; demonstrations; inquiry; conceptual change

Wen-Jye Shyr 585–590 Integrating Bio-energy Laboratory Activities Into a Junior High School Classroom

This study developed a bio-energy laboratory activity as well as an outline for evaluating student performance in the activity. The goal of the study was to design and implement a laboratory procedure and assist teachers in achieving the objectives of the activity. A total of 80 junior high school students went through a six-week laboratory activity. Students' understanding of bio-energy concepts was statistically increased after completing these activities, which effectively introduced students to bio-energy technology. The objective of the activities was for the students to gain an understanding of energy education, as well as a greater confidence in investigating, questioning and experimenting with renewable energy ideas.

Keywords: laboratory activity; junior high school; bio-energy; renewable energy

Fernando G. Torres 591–596 Model Engineering of Ancient and Historical Machines as a Training Tool for Mechanical Engineering Students

Model engineering has played an important role in the development of several technological breakthroughs. Some examples include James Watt's work on the broken Newcomen engine model at Glasgow University, which introduced him into steam engines. Richard Trevithick developed several scale models in order to demonstrate the way of functioning of his early road steam locomotives. Recent advances in computer aided design (CAD) and computer modelling have provided resources for a more virtual oriented education to mechanical engineering students, which may have resulted in a reduction in the actual time dedicated to the construction of real pieces of machinery or equipment. The choice of the type of machines to be modelled also represents a challenge for a curious student, especially if we try to recreate devices engineered by the ancient Greeks, Romans, by Leonardo da Vinci, or the more recent steam and hot air engines. The list of potential devices to be modelled is almost endless. In this paper, we report on a contest for the construction of functional models from the ancient Greeks. We also report on the development of steam and hot air (Stirling) models. The difficulties found by the students during the projects are discussed in terms of the course level of the students and their specific backgrounds and interests.

The construction of operating scale models also represents a good option for university departments with limited budgets, since the amount of materials and production time required is considerably less than what is required for full scale machines. Some suggestions for the implementation of this kind of workshops and contests are also given.

Keywords: model engineering; engineering education; steam engine; historical machine

Javier Galeano, Juan Manuel Pastor and Miguel Ángel Muñoz 597–603 Playing the Rock-Scissors-Paper Game on Complex Networks in Ecology: Motivating Graduates to Learn Complex Networks

The Rock-Scissors-Paper is a game in which two players choose one out of three possible options: rock, scissors or paper. Rock breaks scissors, scissors cuts paper, and paper covers a rock. We use this game model to motivate our students, with heterogeneous backgrounds, to obtain a basic knowledge of Complex Networks and Ecology. In particular, we analyze the behavior of the rock-scissors-paper model, a basic cyclic antagonist ecological model, played at different network topologies: random, scale-free and entangled. One of our main goals is that students scrutinize the topological properties determining optimal persistence of Biodiversity. In particular, our students have studied the extinction time of the 3 species when the size of the complex networks change, keeping the same properties in the nodes of the network. They have performed the simulations on networks with the same average degree $\langle k \rangle = 4$, and with an initial random distribution of the species (rock, scissor, paper). Substantially different behaviors can be found playing in the different topologies. We want the students to understand the influence of the network topology in the outcome of the game; and more general the relevance of the underlying network topology in Game Theory.

Keywords: complex network; ecology; game theory; educational innovation

A. Manuel de Oliveira Duarte, Ilídio C. Oliveira, Hugo S. Félix, David C. Carrilho, Anabela Sousa Pereira and Inês Direito 604–609 Active Classrooms: Role-Playing Experience in Telecommunications Engineering Education

When starting a career many engineering graduates have serious behavioral mismatches and very limited knowledge about the activity sectors and businesses where they become involved. These circumstances can represent an important handicap in their careers and the resulting limitations can significantly impair their capability to play the roles that enterprises expect from them. In addition, these weaknesses also do not favor the emergence of an entrepreneurial spirit among young engineers, restricting their ability to contribute to economical and social growth. Ultimately, all this can jeopardize the capacity of constructing their own work identity and ensuring their employability.

This paper describes the results of an educational project designed to promote improved learning among telecommunications engineering students and enhance their entrepreneurial competences. A didactic market simulator was developed and groups of students played the roles of competing market operators. This project showed an improvement of average marks, the development of teamwork skills, the consolidation of previous knowledge, and a better understanding of telecommunications business markets.

Keywords: role-playing; simulation; telecommunication markets; competences development

Negotiation is defined as a joint decision-making process of two or more parties working together to reach a mutually acceptable agreement on one or more issues. Negotiating is not likely to be taught in conventional classrooms with expositive methodology, as students usually find this boring and insufficiently motivating for them to participate actively. The role playing method is better suited to improving trainees' skills. In this technique, students are asked to role play with others and assume roles in an adapted engineering negotiation. They are given some common information about the scenario, the issues to be resolved or optimized (i.e., the price of a material) and some confidential information that it is unknown by the others (their company negotiation position, etc.). Accepting that role playing is the best method by which to improve negotiating skills, there is a need to test whether combining this kind of game with quickly-provided theoretical knowledge of the principles of negotiation (negotiating positions, kinds of negotiators, etc.) would significantly improve the trainees' results. The purpose of this paper is to describe the research done with students at the ETS of Industrial Engineers of the UPM where a group was homogeneously divided into an experimental and a control group. Both groups of students were asked to participate in three negotiation role plays. The main objective of the experiment was to determine the adequate mix of playing sessions and theory necessary to maximize the students' negotiating skills.

Keywords: negotiating skills; learning by playing; engineering education

This paper presents the development method and process of designing a board game as a new educational experience at the Polytechnic Engineering Faculty of Elche, at Miguel Hernandez University, Spain. The main objective of this educational action is to motivate students to learn general aspects of a subject, by designing, creating, and playing with a traditional board game, using general questions from different areas of knowledge of Acoustics and Acoustical Engineering. During this process, students reinforce skills such as working in a group, decision making and looking for references, in addition to learning the general aspects and fundamental concepts of the subject. As a result of the experience, students show a significant improvement in their knowledge, and a higher motivation to learn more about this subject. Survey results show that they are proud of their work, and they feel that they will turn this teaching experience to their advantage.

Keywords: learn through playing; board game; working in a group

This communication presents a collaborative experience between four Spanish centers: the School of Engineering (ETSE) and the Sports Services Area (SAF) both from the Universitat Autònoma de Barcelona (UAB) jointly with two centers of the Technical University of Catalonia, the Technical school from Vilanova i la Geltru (EPSEVG) and the Technical school in Terrassa (ETSEIAT). The idea behind this collaboration is to explore the possibility of role playing in engineering education and project development for engineering students. The basic principle of such projects is the identification of the corresponding roles associated with the different parts that can be found on current social/industrial activity. In this paper the role playing model is presented: the first part, the role of the partners, and the second part the students' role developing applied projects in human-automation systems.

Keywords: role-playing; project-based learning; human-automation interaction and satisfaction metrics

This paper deals with a method of learning through play for the reinforcement of knowledge and concepts. The act of playing occurs within plays of theater, created by learners, using analogies and metaphors that aim to match technical concepts with situations of the play through dialogues. Students learn through play in different moments of the learning process: during the task of creating the play by looking for funny dialogues and situations where the metaphors and analogies should match with technical concepts; while students are designing the wardrobe and the stage; and when the performance of the play takes place. Creativity of learners is exploited resulting in an improvement of retention of concepts around the topics to be reinforced. This method has been successfully applied in our institution since 2006, for the reinforcement of topics belonging to the course of Integrated Manufacturing Systems in Undergraduate Engineering Programs. In order to assess quantitatively the efficiency of the method in the retention and understanding of concepts two tests have been made before and after the application of the method.

Keywords: learning; play; analogies; metaphors

This study aims to demonstrate that data from business games can be an important resource for improving efficiency and effectiveness of learning. The proposal presented here was developed from preliminary studies of data from Virtual Market games that pointed the possibility of identifying gaps in learning by analyzing the decisions of students. This proposal helps students to refine their learning processes and equips tutors with strategies for teaching and student assessment. The proposal also complements the group discussion and/or debriefing, which are widely used to enhance learning mediated by games. However, from a management perspective the model has the potential to be erroneous and miss opportunities, which cannot be detected because of the dependence on the characteristics of the individual, such as ability to communicate and work together. To illustrate the proposed technique, data sets from two business games were analyzed with the focus on managing working capital and it was found that students had difficulties managing this task. Similar trends were observed in all categories of students in the study—undergraduate, postgraduate and specialization. This discovery led us to the analysis of data for decisions made in the performance of the games, and it was determined that indicators could be developed that were capable of identifying inconsistencies in the decisions. It was decided to apply some basic concepts of the finance management, such as management of the operational and non-operational expenditures, as well as production management concepts, such as the use of the production capacity. By analyzing the data from the Virtual Market games using the indicator concept, it was possible to detect the lack of domain knowledge of the students. Therefore, these indicators can be used to analyze the decisions of the players and guide them during the game, increasing their effectiveness and efficiency. As these indicators were developed from specific content, they can also be used to develop teaching materials to support learning. Viewed in this light, the proposal adds new possibilities for using business games in learning. In addition to the intrinsic learning that is achieved through playing the games, they also assist in driving the learning process. This study considers the applications and the methodology used.

Keywords: business game; teaching-learning process; teaching-learning in the engineering courses

Section II

Selected papers from the 2010 International Engineering Education Conference, Antalya, Turkey

Tania Vasileva, Vassily Tchoumatchenko 656–669 Infrastructure Supporting Collaborative Project Based Learning in Engineering Education
and **Minna Lakkala, Kari Kosonen**

The paper presents a web-based virtual environment aimed to promote project based collaborative learning and continuous work around shared objects. It is designed to provide specific affordances for joint development of shared objects, organizing related tasks as well as user networks and interactions. The environment provides a coherent set of tools in order to initiate and manage collaborative processes, to create, work on and share documents collectively, and to support synchronous and asynchronous communication among participants. A co-design framework, basic features, architecture, as well as supporting tools and their implementation are considered. The results of current field trials with the tools are also briefly outlined.

Keywords: collaborative learning; project-based learning; distributed environment/web-based environment; engineering education

Ahmed F. Salman, Yasser E. Ibrahim, 670–678 Developing of Specifications and Academic Curriculum in Construction Engineering, A case study in University of Dammam, KSA
Mostafa M. El-Shami, Sami Osman
and **Abdulrahman S. Hariri**

Developing an engineering curriculum in order to meet the local and regional market needs is of great importance. Seeking professional and academic accreditation from world-wide organizations, such as National Commission of Academic Accreditation and Assessment in Kingdom of Saudi Arabia and Accreditation Board for Engineering and Technology should be considered. This paper discusses different stages of developing the specifications and curriculum of Construction Engineering Program in the College of Engineering, University of Dammam. Feedback from the main stakeholders in the local area as well as the academic reviewers from well-known international universities is presented and discussed. Comparison between the proposed curriculum with similar accredited programs worldwide is also presented.

Keywords: curriculum; construction engineering; accreditation

Mehmet Canturk and Mohammad Rehan 679–688 Impact of Job Requirements on ICT Curriculum

This study presents an approach to address the issue of keeping curriculum content in synch with the changing demands; in other words dynamic curriculum delivery or dynamic curriculum updating based on a model. In this approach, the analysis of Information and Communication Technology (ICT) job data from the industry, and as well as the ongoing use of expert knowledge from the field of information science keep the ICT curriculum content up-to-date, relevant, and consistent with the educational goals of the universities, and students in a variety of educational and cultural contexts. A number of recommendations are put forward for educating students in Turkish universities in order to enhance their opportunities in the international job market.

Keywords: ICT curriculum; curriculum content updation; ICT programs; ICT jobs; content organization