

The International Journal of Engineering Education

Section I

Special Issue

Learning through Play in Engineering Education—Part 2

Guest Editor

Andrés Díaz Lantada—Universidad Politécnica de Madrid, Spain

- Ahmad Ibrahim** 691 Editorial
Andrés Díaz Lantada 692 Guest Editorial
Jorge Domínguez Domínguez and Jorge Axel Domínguez López 693–702 Learning to Design Experiments Using Computer Simulations

Using software to simulate experiments is a very useful tool in the fields of quality engineering. This allows engineers to acquire the ability to identify the key parameters of a product or process. In this paper, a design of experiments is applied to a helicopter prototype problem which resembles a general engineer problem. This example illustrates the powerfulness of this statistical tool when it is utilized in conjunction with engineering knowledge. In addition, this points out the value of this technique in the industry. Furthermore, with this simulation, the students learn this statistical method developing their own project. Other simulator has been developed to contribute in learning design of experiments: A cannon with several different control factors as well as noise factors. These simulators are two modules of an educational material developed for the teaching and learning of statistics. From our experience, this material and its modules have improved the understanding of statistical concepts and increased the motivation to learn more about it.

Keywords: engineering education; experimental design; helicopter simulator; factorial design

- Erik Delarue, Elisabeth Laga, Leonardo Meeus, Ronnie Belmans and William D'haeseleer** 703–712 Achieving Learning Potentials in an Educational Simulation Game for Trading and Generating Electrical Energy

This paper presents and motivates the development of a techno-economic education package, consisting of two simulation games, to simulate both the trading and the generation of electricity in a liberalized market. Six attributes (storytelling; players as problem solvers and explorers; feedback; challenges that fit the student characteristics; competition; appropriate graphics and sounds) are relevant in order for simulation games to achieve their learning potentials. These attributes are identified within both developed simulation games.

Keywords: energy engineering; liberalized electricity markets; simulation game; learning through play

- A. García-Beltrán J. L. Ocaña, C. Molpeceres, M. Morales, J. M. González, M. Blasco and D. Iordachescu** 713–721 A Virtual Laboratory for Laser Transformation Hardening

The main purpose of this work is to describe the fundamentals and application of a web-based virtual laboratory as a facility to assist undergraduate students of engineering to learn industrial laser applications and to practice laser procedures techniques. Furthermore, this paper presents the pedagogical methodology and the results drawn from this experience. The system helps students to perform laser hardenings of steel and to examine results immediately. Students only need a computer connected to the Internet and a web browser in order to take advantage of all the application functions. The system architecture, the graphic user interface design and an on-line help system eases user interaction with the system.

Keywords: virtual laboratory; web-based system; learning-teaching strategies; laser transformation hardening

- C. Ahnert, D. Cuervo, N. García-Herranz, J. M. Aragónés, O. Cabellos, E. Gallego, E. Mínguez, A. Lorente and D. Piedra, L. Rebollo and J. Blanco** 722–732 Education and Training of Future Nuclear Engineers Through the use of an Interactive Plant Simulator

The successful experience of the Jose Cabrera Nuclear Power Plant Interactive Graphical Simulator implementation in the Nuclear Engineering Department in the Universidad Politécnica de Madrid, for the Education and Training of nuclear engineers is shown in this paper. The paper starts with the objectives and the description of the Simulator Aula, and the methodology of work following the recommendations of the IAEA for the use of nuclear reactor simulators for education. The practices and material prepared for the students, as well as the operational and accident situations simulated are provided.

Keywords: nuclear power plants; interactive simulator; education and training

- P. Lafont Morgado, J. Echávarri Otero, E. Chacón Tanarro, E. de la Guerra Ochoa, A. Díaz Lantada, J. M. Muñoz-Guijosa and J. L. Muñoz Sanz** 733–745 Interactive Simulations of the Performance of Hydrodynamic Bearings in the 'Machine Design' Course

Bearings are very usual engineering components and are used in almost all types of machinery. They are essential for the correct operation of machines because they provide the separation between loaded surfaces in relative motion, through a hydrodynamic lubricant film. In this work, a pilot experience is set out regarding the teaching and learning process of hydrodynamic bearings in the 'Machine Design' course, through play with a helpful interactive system. Its main aim is to encourage students to deal with real mechanical engineering problems, and improve their ability to model, simulate and predict the influence of each parameter on the results, and as a consequence optimize the solution. The hydrodynamic equations are solved numerically by executing a C program, where input parameters are dimensionless minimum film thickness and the ratio of length to width of the bearing. The results obtained are the following dimensionless parameters: pressure and film thickness distributions, load capacity and bearing characteristic numbers. Finally, a post-processing using Matlab software allows deducing dimensional values of the cited

parameters, and also determining other related results such as temperature, friction coefficient, lubricant flow and lubricant lateral losses. In addition, it provides a graphic representation of the results of interest. The system developed is organized in modules which are fully controlled using different applications in Matlab, which interact with the C program when necessary. Teaching and learning modules consist of interactive and parameterized applications, designed for non-expert Matlab users, which deal with practical situations. The modules developed have shown themselves to be useful for learning the mechanisms of hydrodynamic film generation and for analyzing the effects of operating variables on the performance of such films, like variations in load, velocity, eccentricity, design parameters, etc. In addition, they are suitable for deductive teaching and learning purposes.

Keywords: Journal bearing; hydrodynamic lubrication; Machine Design; learning module

Juan J. Marquez, M. Luisa Martínez, Gregorio Romero and Jesus M. Perez 746–756 New Methodology for Integrating Teams into Multidisciplinary Project Based Learning

This paper describes the collaboration among students and professors in four different subjects, to develop multidisciplinary projects. The objective is to simulate the conditions in a company environment. A new methodology based on student interaction and content development in a Wiki environment has been developed. The collaborative server created an 'out of the classroom' discussion forum for students of different subjects, and allowed them to compile a 'project work' portfolio. Students and professors participated with enthusiasm, due to the correct well-distributed work and the easiness of use of the selected platform in which only an internet connected computer is needed to create and to discuss the multidisciplinary projects. Quality of developed projects has been dramatically improved due to integration of results provided from the different teams.

Keywords: PBL; active learning; collaborative work; multidisciplinary approach; mechanical engineering hands on teaching

Rosa Arnaldo Valdés Luis Perez Sanz and José Felix Alonso 757–765 The use of Flight Simulators for Airspace Design in Engineering Education

To facilitate the safe, orderly and expeditious flight of aircraft from one airport to another, airspace structures, such as airways, departure and arrival instrumental flight procedures and holding patterns, are defined in the airspace. The criteria and principles of Airspace and procedures are part of the syllabus of the Aeronautical Engineering degree at the Escuela Universitaria de Ingeniería Técnica Aeronáutica (EUITA) [University School of Aeronautical Technical Engineering] of the Universidad Politécnica de Madrid [Polytechnic University of Madrid]. To help students to master the theory and practice required, a specific course, in the latter stages of the degree, is devoted to this discipline. The course includes both a theoretical part, in which the principles behind the standards are introduced and explained, and a practical part where the theory is applied. This final part consists of two main activities: firstly, the students design the procedures, and secondly, these use these same procedures to fly, on a low cost flight simulator cockpit, under teaching staff supervision. In this students can see the results of their work and better assimilate the design principles. The flight simulator has been specifically developed for this purpose by professors of the Infrastructure, Aerospace Systems and Airport Department, and is based on a commercial 'off the shelf' flight simulation videogame, called X-plane. The professors have also created a complete practice program on the simulator, so that the student can better understand how instrumental flight procedures impact on aircraft operation.

Keywords: Videogame; flight simulator; airspace structures; flight instrument procedures; aeronautics; engineering

Jayson W. Richardson, Tamara J. Moore, Gregory C. Sales and Matthew V. Mackritis 766–777 Using Computer Simulations to Support STEM Learning

In this study we investigated the implementation of a computer-based simulated Model Eliciting Activity (MEA). The sample included 30 students who completed a paper-based MEA and 60 students who completed a computer-based MEA. Results from both sets of students were compared using cognitive task analysis to determine if the MEA delivery format had an impact on how students: 1) defined the tasks, 2) determined appropriate variables to include in their analysis, 3) implemented correct mathematical analysis, and 4) communicated the results. It was found that students who used the computer-based MEA performed equally well on the first two factors but performed significantly better on the last two factors. Suggestions for improving the simulated MEA game are included.

Keywords: Model-Eliciting Activities; MEA, simulations; technology; problem-based learning; STEM

Thashika D. Rupasinghe, Mary E. Kurz, Carl Washburn and Anand K. Gramopadhye 778–788 Virtual Reality Training Integrated Curriculum: An Aircraft Maintenance Technology (AMT) Education Perspective

This paper presents results from a 3-year National Science Foundation: Advanced Technology Education (NSF: ATE) funded initiative to enhance curriculum and student learning via integration of Virtual Reality (VR) technology-based simulators. An Aircraft Maintenance Technology (AMT) curriculum is the backbone of training and educating maintenance technicians for the aviation industry to function in safe operating conditions. As a part of this research effort, the ViSIns Laboratory (Virtual Simulated Inspection Laboratory) was established at Greenville Technical College, South Carolina, USA; to reduce the gap between high-end technology requirement in the hangar (work environment) and the classroom. Using Bloom's Taxonomy in the cognitive domain, learning objectives of six course modules were refined to create more meaningful student outcomes and mapped to reflect expected student proficiency and goals. The pedagogical material development was extended to integrate two Non-Destructive Inspection (NDI) simulators (borescope and eddy current) in classroom activities and learning as interactive 3D knowledge objects. We present results on student learning using the VR augmentation on different sub-domains of cognition. Our results indicate that VR simulators are effective 3D learning objects which can be used for enhancing deliverables of the AMT education. This study further contributes to engineering education, aircraft maintenance technology education improvement and the use of VR-based simulators in technology driven training environments.

Keywords: curriculum; education; technology; training; and virtual reality

Susanne Ihnen, Wolfram Schneider, Frank Wallhoff and Jürgen Blume 789–794 Raising Interest of Pupils in Engineering Education Through Problem Based Learning

In 2009 within the Excellence Initiative of the German federal government and the state governments a project called 'LearnING' started at the Technische Universität München. Aim of this project is to trigger the interests of pupils and students towards robotics, cognitive systems and engineering. With the approach of Problem Based Learning gender specific aspects during the implementation of courses in school should be considered and designed gender equitable to get more girls interested in this field. By now two educational modules were implemented, one in primary school and one in secondary school. Both modules were evaluated; the data for the secondary school is already available.

Keywords: Problem Based Learning; Cluster of Excellence; Engineering Education; Gender and Diversity

María Ángeles Andreu-Andrés, and Miguel García-Casas 795–804 Perceptions of Gaming as Experiential Learning by Engineering Students

After defining the term game and its characteristics, this paper refers to the origins of games, and supports the idea of gaming as one of the techniques included in the simulation and gaming methodology endorsed by associations such as ISAGA, NASAGA, JASAG, ABSEL or SAGSET.

Considering gaming as experiential learning this study offers the perceptions of forty seven engineering students in their third year of studies at the Universitat Politècnica de València (Spain) regarding the use of games in different supports as part of their

activities to gain knowledge in subjects of their degree program throughout a semester, to reinforce previously covered material, and to help learners develop problem-solving skills, communication and teamwork skills.

A review of the advantages and drawbacks of using games leads us to carry out the statistical analysis of the answers to a survey concerning the use of gaming as a teaching-learning technique with these engineering students, the students' experience with games in different subjects attended before and during their university studies, and the students' perceptions on using games to learn or just for fun.

The study of the relation among the variables analysed allows us to perceive the students' feelings regarding gaming as opposed to more conventional strategies. As a whole, engineering students participating in the experiment back experiential learning and confirm that they learn and have fun when there is gaming in class activities.

Keywords: gaming; experiential learning; students' perceptions; higher education

R. Antón, J. Gastelurrutia, J. C. Ramos, 805–812 Learning through a Multiple Approach Competing Practical Exercise—
A. Rivas and G. S. Larraona MACPE: a Case Study with a Teacher's and a Student's Assessment

A Multiple Approach Competing Practical Exercise (MACPE), is an open exercise that confronts a group of students with a practical engineering problem using their own resources and choosing among multiple approaches in a competing environment. A case study with a teacher's assessment and a student's assessment has shown that this sort of exercise is able to motivate the students' learning process. It has also been found that it is a fun way to foster team work and constitutes an open door to innovation.

Keywords: student competition; practical case study

J. Carpio Cañada, T. J. Mateo Sanguino, 813–820 From Classroom to Mobile Robots Competition Arena: An Experience on
S. Alcocer, A. Borrego, A. Isidro, Artificial Intelligence Teaching
A. Palanco and J. M. Rodríguez

This paper presents an educational experience developed in the fourth year of Computer Science degree at Huelva University (Spain). To make Artificial Intelligent (AI) learning processes more captivating, a new educational project was incorporated into classical teaching of Artificial Intelligence and Knowledge Engineering subject. In this paper, we present the experience fulfilled with a group of college students. Here it is related how they changed for some days their classroom lessons for the robotic competition arena. With this project we have extended regular classroom lessons with additional work that could be useful and cannot be provided by traditional practical lessons, the real life experience. As a real example about how the work was accomplished we describe the mechanical construction of the mobile robots as well as the software development process.

Keywords: artificial intelligence; engineering education; gaming; robotic competition

Manuel A. Forero Rueda and 821–830 Innovations in Undergraduate Engineering Mechanics Education: Use of
Michael D. Gilchrist Team-Based Research-Led Project Methods for Large Student Cohorts

As a cornerstone subject for all undergraduate engineering degree programmes, mechanics is best taught from fundamental principles and by reinforcing students' learning through active learning strategies. This approach provides students with a solid understanding of basic concepts before they subsequently study more advanced topics such as dynamics, control, solid mechanics and fluid mechanics. MEEN10030, Mechanics for Engineers, is a compulsory module taught annually in Semester I to 260 First Year students at University College Dublin, Ireland's largest university. The syllabus topics include forces, Newton's laws of motion, statics in two and three dimensions, equilibrium, friction, trusses and cables, distributed forces, centres of mass and centroids, motion, and kinematics of a particle and of a rigid body.

Traditional teaching of this subject relies solely on formal lectures and tutorials, without any laboratory sessions or student assignments, both of which are resource intensive. Five years ago, following a programme review in 2006, this module was completely revised and the subject material was rationalised with regard to what is taught in subsequent Second Year modules. Three entirely integrated laboratory sessions were developed so that groups of students would complete a variety of analytical and enquiry-led exercises in numerical, graphical and written form. A more recent additional major initiative, introduced three years ago in 2008, provides team-based assignments to the entire 260 students in which groups of up to five students are set a design challenge directly related to one specific topic from the course material. These changes have proven popular with students and have led to improved learning outcomes and student performance without compromising on academic standards. This paper describes these innovative developments in which Irish engineering students have opportunities for research-led active learning in this manner.

Keywords: research-led; team-based; undergraduate teaching; design project

Carlos Veganzones, Sergio Martínez, 831–837 A Learning Through Play Approach to the Development and Assessment
Jaime R. Arribas, María E. Díaz, of General Competences in Electrical Engineering Based on a Student
Dionisio Ramírez, Francisco Blazquez Competition
and Carlos Platero

Student competitions are commonly used as part of engineering education curricula. This paper describes 'Race with the Wind', an international student competition to design and build wind generators, and presents an analysis of how the competition contributes to the acquisition of general competences within the Electrical Engineering curriculum at the Universidad Politécnica de Madrid.

Keywords: competences; learning through play; student competition

Section II

Contributions in: Engineering Thinking, Scientific Reasoning, Assessment, Cooperative Learning, Active Learning, Interactive Learning, Peer Instructions, Electric Machinery, Computer Programming, Statistics, Thermodynamics, and Refrigeration

Shlomo Waks, Elena Trotskovsky, 838–851 Engineering Thinking: The Experts' Perspective
Nissim Sabag and Orit Hazzan

Most student graduates in engineering schools are involved in engineering design, that is, the development of new products for which engineering thinking is required. Our literature survey, however, did not yield material pertaining to engineering design thinking in the field of electrical and electronic engineering. Therefore, we propose to clarify the term 'engineering thinking'. Specifically, this paper presents a characterization of engineering thinking in general, and electric and electronic engineering

thinking, in particular, from the point of view of experienced engineers. In addition, to highlight the uniqueness of engineering thinking, we compare engineering thinking in engineering design and research thinking in scientific research in the area of the exact sciences.

Keywords: engineering design; engineering design thinking; experts; characterization

Maher Al-Arfaj 852–858 Scientific Reasoning Abilities of Undergraduate Science and Engineering Students at King Faisal University

Science is a discipline that uses experimentation and thought to study various aspects of nature. A major prerequisite for training young students to be future scientists is to hone their scientific reasoning abilities. In addition, students enrolled in engineering studies should be acquainted with scientific reasoning abilities in order to form creative solutions and applications. The present study was conducted at KFU to assess scientific reasoning abilities among first-year engineering and science undergraduate students. A Scientific Reasoning Test was administered, then the students were categorized into three levels of scientific reasoning: Empirical Inductive (low-level), Transitional (average), and Hypothetico Deductive (high-level). As a result, most of the students fell into the Empirical Inductive level and no significant difference was depicted between science and engineering students. Furthermore, in the Test, items regarding ‘Conservation of weight’ have the highest percentage of right answers (95.12%), followed by items about ‘Conservation of displaced volume’ (63.4%). On the other hand, the lowest percentages of right answers correspond to items of ‘Identification and control of variables’ (20.7%) and items of ‘Hypothetico-deductive thinking’ (19.5%).

Keywords: education; research projects; thinking; deductive thinking; inductive reasoning

A. F. Almarshoud 859–866 Developing a Rubric-Based Framework for Measuring the ABET Outcomes Achieved by Students of Electric Machinery Courses

Quality assurance systems of academic programs necessitate a continuous improvement process. In this process the program outcomes should be measured and assessed using a sound assessment technique. The results of the evaluation of the outcomes should then be used to develop and improve the program. Continuous assessment of the curricula outcomes is considered the cornerstone of the continuous improvement process. Previous works have presented a framework to assess and evaluate the ABET general outcomes of engineering programs. These frameworks are universal for all engineering disciplines, but they are not tailored for assessing the outcomes of a specific subject. The purpose of this paper is to assist the instructors of electric machinery courses to assess and evaluate the outcomes related to these courses. A framework has been constructed based on a rubric system for each expected outcome of the machinery courses. The suggested assessment levels are designed according to Bloom’s taxonomy.

Keywords: ABET; assessment; EC-2000; outcomes; accreditation; rubric; Bloom’s taxonomy

Miguel Arevalillo-Herráez and José M. Claver 867–874 Assessment Technique to Encourage Cooperative Learning in a Computer Programming Course

Cooperative learning has been reported to produce greater student achievement than other traditional learning methodologies. However, difficulties are usually found with plagiarism and with achieving the equal commitment of all members. In this paper, we propose a teaching methodology that aims at avoiding plagiarism, promoting cooperation and encouraging participation of group members. To this end, a number of collaborative tasks are set using a typical Problem Based Learning (PBL) approach. Instead of evaluating student performance by means of a typical report (or portfolio), students are assessed by means of a written test, composed of questions that are closely related to the collaborative task. Furthermore, student grades are made dependent on the individual grades obtained by all other members in the group. In this way, students are encouraged to help each other, and their level of commitment is increased. This technique has been applied to a group of 46 students taking the ‘Programming Languages’ module, a third level module of the Degree in Computing at the University of Valencia (Spain). Results have shown a significant improvement in student performance. Moreover, individual questionnaires have provided evidence that students prefer this technique to other more conventional teaching methods.

Keywords: collaborative learning; active learning; problem based learning; plagiarism

Huei-Chun Huang, Shen-Guan Shih and Wei Cheng Lai 875–884 Cooperative Learning in Engineering Education: a Game Theory-Based Approach

This paper describes some findings derived from teaching a class of engineering students organized into cooperative learning groups. We used the “iterated game” and “intergroup competition” based on game theory for group arrangement and class management so that students were encouraged to learn cooperatively. The performance of the cooperative learning class was compared to other classes that did not implement cooperative learning groups. The results indicate that students in cooperative learning class significantly outperformed students in other classes. Student feedback showed that cooperative learning effectively lifted student motivation to learning.

Keywords: cooperative learning; game theory

Andreja Drobnic Vidic 885–896 Impact of Problem-based Statistics Course in Engineering on Students’ Problem-Solving Skills

In this comparative study, we examined the level of basic discipline knowledge and problem-solving abilities in problem-based learning (PBL), incorporated into a traditional curriculum in an introductory statistics course. Progressively less structured, less familiar and more open problems were presented to engineering students. Engineering problems triggered the learning of new statistical contents and activated small group problem solving. Students as a group determined the learning goals, individually searched for information, and together analysed the information collected. Such a problem-solving process with real-world problems is often seen as unstructured and time-consuming. An experiment was carried out to find out whether this approach yields adequate basic statistical knowledge and improves problem solving. Two randomised groups of students from the same engineering programme were compared: one group used PBL and the other followed the traditional method of instruction. The results of statistical analysis showed that engineering students with the PBL approach acquired sufficient basic statistical knowledge and were better able to solve statistical problems from the field of engineering than the students who followed the traditional way of instruction. Some characteristics of the implementation of the course are discussed, as well as some limitations of the study.

Keywords: undergraduate engineering; statistical knowledge; problem-based learning; problem-solving skills; comparative study

Milo D. Koretsky and Bill J. Brooks 897–908 Comparison of Student Responses to Easy and Difficult Thermodynamics Conceptual Questions during Peer Instruction

This study investigates the use of Peer Instruction in an upper division chemical engineering thermodynamics course. Peer Instruction is a technology-supported active learning pedagogy where each student in the class participates; it is often used with classroom response systems (clickers). In its typical implementation, the students are asked a multiple-choice conceptual question, they respond individually, self-select small groups to discuss the answer, and then respond again individually. The instructor can then display the results and lead a class-wide discussion. In order to apply this pedagogy most effectively, a better understanding of student thinking during Peer Instruction is needed. In this study, students were asked to provide short written explanations with their multiple choice responses. Through analysis of these responses, catalogued by group, we seek to identify how the student–student interactions during Peer Instruction influence conceptual development. Two questions where students needed to apply an energy balance are compared. In one of the questions, few students answered correctly while many students answered the other question correctly. In both cases, approximately one-quarter of the students’ written explanations improved after group discussion;

however, in the case of the difficult problem, a significant portion of other students' explanations got worse. Analysis of the written explanations showed that in both cases many students failed to identify that an energy balance was needed and instead resorted solely to the ideal gas law in their explanation. Results are discussed in the context of a cognitive resources-based framework and in terms of a sociocultural perspective of learning.

Keywords: peer instruction; educational technology; active learning; thermodynamics

R. Cabello, R. Llopis and D. Sánchez 909–918 REFLAB: An Interactive Tool for Supporting Practical Learning in the Educational Field of Refrigeration
and **E. Torrella**

A new interactive tool for supporting practical learning in the educational field of refrigeration is presented in this paper. The application, called REFLAB, is used for on-line representation of the main operating variations in real refrigeration plants, such as cooling capacity, power consumption and coefficient of performance. The implementation of this interactive tool covers two groups of practical lessons, in which students operate with two refrigeration plants (a single-stage and a two-stage) and obtain, by means of its graphical interface, the effects produced by changes in the operating conditions. The use of REFLAB allows a quick comprehension of the theoretical concepts explained in class and an intuitive assimilation of the behaviour of the refrigeration plants. The aim of this paper is to explain how the interactive tool works and which are the main objectives pursued in the practical lessons. The paper includes a series of graphical animations that simulate the practice lessons received by the students.

Keywords: interactive learning, refrigeration, vapour compression plants, practical lessons