

The International Journal of Engineering Education

Contents

A. Ibrahim	1075	Editorial
Jos van Schijndel	1076	Guest Editorial

Part I

Special Issue: COMSOL in Engineering Education

Guest Editor: Jos van Schijndel

Eindhoven University of Technology, Netherlands

A. J. Baker, S. Sahu, M. A. Grubert and S. C. Ericson	1077–1091	Getting Smarter about Accuracy Tuning Multi-Physics Simulations
--	-----------	---

Finite element analysis (FEA) has totally penetrated industry in support of engineered systems design optimization. Over its half century of development, numerous commercial FEA codes have been created to support the distinct engineering disciplines constituting continuum mechanics. Conversely, modern engineering systems design spans multi-disciplines requiring multi-physics analyses of the type supported by COMSOL. As many practicing computational design engineers matriculate without formal academic exposure to the theoretical underpinnings of FEA, familiarity with quantitative assessment protocols for estimating engineering accuracy of multi-physics predictions is weak. The solution to this technical base shortfall is detailed.

Keywords: finite element analysis; problem solving environment; error estimation theory; solution adaptive mesh refinement; engineering accuracy

K. K. Bhatia	1092–1096	Application of Finite Element Software to Bridge the Gap between Hand Calculations and Experimental Results in Undergraduate Heat Transfer Education
--------------	-----------	--

A project involving the design, building, and testing of a hot liquid thermos was implemented in a junior level mechanical engineering heat transfer class. Finite element analysis (FEA) software was used to bridge the typical gap between hand calculations of heat transfer performance and experimental results. On average, student hand calculations over-predicted the thermos's thermal resistance by 124% as compared to experimental results. FEA, in the hand of undergraduate students, over-predicted the thermal resistance by only 33%. Student self-assessment survey results showed an overall positive feeling regarding the project. Despite the increased accuracy of FEA, 60% of students indicated that hand calculations were a more useful design tool, 65% indicated that they learned the most from hand calculations, and 75% indicated that hand calculations would be the future method of choice when heat transfer problems arise.

Keywords: finite element; heat transfer

P. J. Butler	1097–1104	Motivating Undergraduates to Use Their Engineering: Integrating COMSOL Multiphysics and Designs for World Health
--------------	-----------	--

Humanitarian engineering design problems can be used to motivate students to learn finite element analysis software. Specifically, health-related projects originating from needs in developing countries are assigned to teams of undergraduate juniors in Bioengineering, and COMSOL multiphysics is used to assess whether designs meet quantitative design criteria. Survey results suggest that this method is effective in helping students use engineering principles such as transport phenomena, heat transfer, and solid and fluid mechanics to assess feasibility of designs ranging from pediatric ventilators to electrosurgical pens. We conclude that the humanitarian engineering design theme motivates students to learn COMSOL multiphysics thus reinforcing technical and professional skills necessary to prepare them for modern engineering practice.

Keywords: finite element analysis; humanitarian engineering; bioengineering; biomedical engineering

R. J. M. Bastiaans	1105–1113	Design Optimization of the Double Glass Problem: Application and Limitations of CFD
--------------------	-----------	---

A simple teaching example of optimization in fluid mechanics is given, where use is made of Computational Fluid Dynamics (CFD). This was carried out on the basis of the assumption that students are trained at a basic level in CFD. In the future, automatic optimization procedures will become very important in design problems. However, it must be emphasized that optimization in fluid mechanics is mostly not trivial. With automatic optimization, the problem formulation must be kept within its applicability range. Moreover, with geometric parameter variation, the (automatic) grid generation and refinement must be appropriate to obtain accurate results. Furthermore, the accuracy of the applied models in the equations must be in general better than the gain in optimization function. In order to illustrate these issues to students, an exercise is compiled using the modeling of double glass windows. The analysis (student assignment) is performed with the aid of COMSOL 3.4 with MATLAB.

Keywords: CFD; optimization; design; natural convection; double glass

E. Holzbecher and C. Kohfahl	1114–1123	The Use of COMSOL Multiphysics in Teaching Groundwater Flow and Transport
------------------------------	-----------	---

For teaching groundwater flow and transport we currently apply COMSOL Multiphysics software. We have two main goals. At first, to familiarise course participants with the basic concepts and phenomena of the subject. Second, to enable students to handle a modelling tool in general. We describe the fundamentals and give examples of exercises that include several features of the modelling options. The multiphysics concept, on which the software is built, is best suited for the modelling of hydrogeological systems, in which flow and transport are connected or even coupled. The user-friendly design of COMSOL makes the software well-suited for use in the class-room for both the above-mentioned purposes. The students benefit from the easy handling of model input, which is completely performed within the graphical user interface. Most striking are the post-processing options for numerical and graphical output.

Keywords: groundwater flow and transport; saltwater intrusion

This paper presents a novel ‘touch and see’ approach for interactive teaching of dynamic stress/strain distribution in engineering education. Our Augmented Reality application visualizes Finite Element Method (FEM) results overlaid over the real model. The user can interactively change the boundary conditions of the simulation and then evaluate the stress distribution in real time. Marker based video tracking is used to measure displacements while COMSOL Multiphysics solves the structural FEM analysis. A cantilever test case has been implemented and evaluated. We describe the optimization solutions needed to achieve real-time simulation and precise and stable tracking. The presented system demonstrates significant educational benefits making the student’s experience more attractive and effective.

Keywords: augmented reality; active learning; FEM; tangible interfaces

A course in computational fluid dynamics (CFD) at the senior or first-year-graduate levels has traditionally emphasized an understanding of the numerical techniques involved, i.e., finite difference, finite volume, or finite elements, followed by a project in which the student writes his or her own Navier–Stokes solver for a simple flow geometry. The educational pedagogy of this format is that the only way one could truly learn and appreciate CFD was to work through the underlying nuts-and-bolts of these respective methods. The evolution of CFD software over the last twenty years has brought us to the point where a challenge to this traditional pedagogy is in order. In this paper, a CFD course given during the Spring 2007 term at the Georgia Institute of Technology will be described. The course was based on the idea that a tool to successfully solve the Navier–Stokes and continuity equations is available, called COMSOL Multiphysics. The course involved the exploration of a number of fluid flows with the aim of developing a deep understanding of the underlying fluid mechanical mechanisms involved in the flow. Along the way, the student learned about the finite-element method used in the software, how to properly pose the underlying mathematical model for the fluid flow, and about the limitations of the modeling process itself. Specific examples from the course that illustrate these ideas are presented and discussed.

Keywords: undergraduate fluid mechanics; computational fluid dynamics; CFD; numerical flow laboratory; fluid mechanics education

We use the multiphysics package COMSOL for teaching heat and moisture transport modeling in the research area of building physics. It includes a description of how COMSOL works and six exercises with 2D, 3D, steady state and transient models. It is concluded that COMSOL is a very useful tool for this kind of engineering education. Especially, the abstraction level of working with partial differential equations (PDEs) has the advantage that the theory (also based on PDEs) can be relatively easily implemented in the models.

Keywords: modeling; building physics; multiphysics; heat; moisture

For engineering education students, solution of an electric-thermal multiphysics problem by using COMSOL program which is based on finite element method has been presented. In considering the problem, the current-carrying capacity and heat distribution of power cables buried in soil were determined depending on the thermal conductivity of the surrounding soil and different buried depths, from the temperature distribution calculations using COMSOL (FEMLAB). The electrical losses due to the current flowing in the cable conductor and electric field which heats up the cable was taken into consideration in the heat conduction equation, to accommodate the electrical losses in calculating the current-carrying capacity. The results show that the current-carrying capacity of the cable with increasing conductivity is increased and wind velocity has a low influence on the current-carrying capacity. Also humidity content in insulating material has an important effect on increase in the temperature of power cables because of increasing insulation conductivity after a certain temperature.

Keywords: power cable; thermal analysis; FEM; multiphysics analysis; COMSOL

Part II

Contributions in: Robotics, Simulators, Computing Tools, Video Games, Visualization, Engineering Education Management, Assessment, Students’ Success, Curriculum Development, and Global Engineering

Although virtual robotic laboratories can be suitable for the teaching of robotics at a basic level, in-depth and, above all, more professional learning requires a real knowledge of the robotic cells and a direct contact with their components (robot arm, controller, programmer, input and output devices, etc.). In order to improve the practical teaching, a prototype of a functional module for the connection of inputs and outputs has been designed and manufactured. The developed module improves the performance of the cell in precision assembly operations as it simplifies the robot’s communication with the peripheral sensors, allows a quick adaptation to the changes required by the cell and rationalises the methodology for the connections. The tests made with the connection module have shown that the tool has a wide scope for university teaching of manufacturing cells as it enables the students to understand clearly the multiple connections of the devices to the controller, allowing the system to be handled safely and simplifying the programming of its operation.

Keywords: robots; assembly cells; input–output interface; teaching

This paper describes some aspects of new teaching software and its academic application. This program is an alternative for enhancing and improving the resources available for students to acquire practical knowledge in plastic injection moulding parameterisation. An injection moulding simulator has been developed that allows preliminary machine capacity determination, an analysis of the number of cavities, in order to define the injection cycle parameter, and defects analysis and its representation. The simulator is used by students on the plastics injection course. The environment allows the student to carry out an iterative process in order to optimise the injection moulding process parameters. All decision-making is based on an Expert System whose response is similar to that of a skilled machine operator.

Keywords: injection moulding; simulation; plastics; virtual reality; simulator

F. Reventós, C. Pretel, L. Batet, J. Izquierdo and M. Arànega 1183–1193 Teaching Basic Pressurized Water Reactor Core Thermal-Hydraulics Employing Worksheet-Based Exercises

The Technical University of Catalonia (UPC) is involved in many initiatives devoted to the examination of new approaches both to teaching organization and to the methodology used. Teaching basic thermal-hydraulic analysis of nuclear plants to students having their first contact with nuclear technology is a challenging activity in Nuclear Departments and Institutes. An important background in computing and numerical algorithms seems to be needed from the very beginning and the student has to understand physical phenomena and aspects of engineering. Traditionally the challenge was apparently solved by only selecting candidates who had a high level in all these skills for nuclear technology studies. This paper explains how, by using a properly organized worksheet, a very limited number of teaching sessions, together with corresponding study on the part of the student, provide interesting results to consolidate knowledge of the most relevant aspects of Pressurized Water Reactor (PWR) core thermal-hydraulics. We do not offer a full description of the tools used, but provide the most relevant aspects and we describe the educational experience of both its development and use. We give some detail of how, from the very beginning, easy calculations are performed by the student using a standard worksheet which enables him or her to concentrate on concepts and parameters related to phenomena and thus on general understanding of the basic overview of the physics involved. All of this is supplemented with simple, but realistic results produced by the student. The worksheet has been tested and is currently being used successfully at the UPC.

Keywords: pedagogy; active learning; educational experience; didactic computing tool; thermohydraulics of nuclear power plants; heat transfer

J. Martín-Gutiérrez, J. L. Saorín, N. Martín-Dorta and M. Contero 1194–1204 Do Video Games Improve Spatial Abilities of Engineering Students?

This paper analyses the relations between the spatial abilities of first year engineering students and the use of certain types of video games. The study was carried out with Mechanical, Electronic and Civil Engineering students at the University of La Laguna (Spain) during the 2007/2008 academic year. An intensive training course on spatial abilities was conducted, using only video games as a learning tool. The video games were used on two different platforms: personal computers (PC) and handheld video games consoles (Nintendo DS). This console was chosen as it was the only one that offered the possibility of playing interactively with the screen, using an electronic pencil. The game chosen was Tetris because there is a PC and a Nintendo version, and it requires spatial abilities to play. Spatial abilities were measured by two tests: the MRT and the DAT: SR. From the results obtained, we can conclude that video games are a good strategy for improving spatial abilities.

Keywords: spatial abilities; video games; MRT; DAT: SR; electronic pencil, Tetris

M. Garmendia, J. Guisasola and E. Sierra 1205–1211 Teaching Part-Visualization: an Approach Based on Problem-Solving Strategy Knowledge

Part visualization, which refers to read and understand any technical drawing, is a fundamental skill in engineering. However, engineering students show certain learning difficulties and a high failure rate in subjects such as Engineering Graphics. The main aim of this study is to introduce a new teaching strategy for part visualization. A problem-solving model for visualization has first to be designed. Teaching strategies may then be applied, by drawing up a programme of specific tasks which takes into account the theoretical contents and procedures involved in part visualization and students' main difficulties and deficiencies when solving this kind of problem. After testing the method in the classroom, the results which were obtained from test and control groups were contrasted, showing an important improvement.

Keywords: part-visualization; teaching strategy; problem-solving model

E. A. Danilova and Z. J. Pudlowski 1212–1217 The Visual World of Engineers: Exploring the Visual Culture of Engineering as an Essential Element of Communication from Design to Production

In the 21st Century world visual intelligence is considered to be a crucial and valuable ability. This digital century, with its rampant development of technology and the availability of alternative communication channels, is changing the way in which people think, as well as their thinking patterns, and the speed of communicating and accessing information. There is everyday exposure to various forms of visual representations of information such as timelines, symbols, tables, graphs, signs, spreadsheets, billboards, etc. Visual forms of communication may carry the information more clearly and effortlessly than the written and spoken forms of communication. It is believed that 'a picture is worth a thousand words'. Indeed, the amount of information that the human being is surrounded with is overwhelming and visual communication is one of the ways to compact and yet clarify this information. Moreover, visual communication may help to deliver information in a way that transcends language barriers. Therefore, imagery is often preferred in operation manuals, aeroplane safety instructions, danger and caution warnings, etc. Visual intelligence and visual cognitive ability are issues in engineering education that would be defined as critical by engineering educators and reflective practitioners. The nature of the engineering profession requires the specialists in the field to be visually literate. The issues of forming the visual culture of engineers are described and discussed in this paper.

Keywords: visual intelligence; visual culture of engineers; technical communication

T. Siller and G. Johnson 1218–1225 Management Structure Designed to Facilitate Changing Engineering Curricula

We have designed a management structure of an engineering program to facilitate innovation and change. Our focus is on the faulty and the tight coupling that occurs between faculty, professional disciplinary societies, accreditation, and curriculum. The concept of loosely coupling the design and management of an engineering program in relation to external stakeholders has resulted in approximately 20 different curricular options being offered during the program's 45-year history. Currently, the program has five options, one of which, precollege teacher preparation, is the first of its kind in the USA. A key to the success of this program has been the flexibility that results from having a loosely coupled system of faculty, management, accreditation, and curriculum. As engineering programs are being increasingly asked to accommodate changes given a changing global profession, schools must find ways to expedite this process. The management structure described exemplifies how programs may facilitate program changes.

Keywords: loose coupling; management; engineering; curriculum development

S. R. H. Hoole 1226–1235 Establishing a Computer Science Program with Staff Shortages in a Developing Country through an Electrical Engineering Department

Development experts, in the wake of the IT revolution, generally see Computer Science as a pathway to advanced economic status bypassing industrialization. Many countries have therefore made IT development a high priority and universities have been charged with and pressured into rapidly developing suitable academic programs in Computer Science. In the Third World where human resources in high-tech fields like Computer Science are scarce, a successful Computer Science program can be developed through an Electrical Engineering Department. The resulting failures and challenges in developing such a program in a developing country context are described. Such successful programs can be sustainable, particularly if they are located physically close to the metropolis.

Keywords: Education; Computer Science; Electrical Engineering; Staffing; Visiting Faculty

H. Gurocak 1236–1248 Planning and Implementing an Assessment Process with Performance Criteria for ABET Accreditation

One of the most challenging criteria for engineering programs to meet for successful ABET accreditation is the Criterion 3 Program Outcomes. In this criterion, ABET requires the program to demonstrate the extent to which each outcome is met by the program. This requires a good mix of direct and indirect assessment of student performance, systematic data collection, assembly, analysis and evaluation. But the main challenge is the development of measurable learning outcomes. This paper presents an approach that defines a set of performance criteria for each program outcome to convert all program outcomes into measurable learning outcomes. The performance criteria create a middle layer between course outcomes and the program outcomes. Primary steps for planning such an assessment system as well as the analysis approach developed to assemble the data coming from various assessment tools are explained in detail. The assessment approach presented in the paper can be a good model for new institutions or programs seeking ABET accreditation. It can also provide ideas for existing programs that have already been through previous assessment cycles.

Keywords: ABET; accreditation; assessment; evaluation; performance criteria; outcomes; objectives

C. Mobley, C. E. Brawner and M. W. Ohland 1249–1256 The South Carolina Merit Scholarship: Strategies Used by Engineering Students to Keep their LIFE Scholarship

We have examined the effects of South Carolina's LIFE merit scholarship on the decisions of engineering students at Clemson University. In Spring 2007, we interviewed 16 current and former engineering majors to learn more about their experiences negotiating their LIFE scholarship eligibility. While the LIFE scholarship influenced their decisions to attend Clemson, it had little influence on their decision to major in engineering. The students used a number of strategies to retain or regain their scholarship eligibility, including being selective about courses and professors, seeking grade redemption, attending summer school, studying harder, and seeking extra help. While merit-based scholarships seem to influence whether engineering students engage in certain behaviors, their reasons for doing so seem to be related less to financial issues and more to the belief that grades are important, a belief which is reinforced by the scholarship rules.

Keywords: engineering pipeline; engineering scholarship; LIFE scholarship; merit scholarships; scholarship retention strategies

M. M. Dewoolkar, L. George, N. J. Hayden and D. M. Rizzo 1257–1269 Vertical Integration of Service-Learning into Civil and Environmental Engineering Curricula

Department level reform efforts funded by the National Science Foundation were instituted for the civil and environmental engineering (CEE) programs at the University of Vermont. The overall goal of the reform was to educate and have students apply a systems approach to civil and environmental problems. A key strategy for practicing a systems approach was through service-learning (S-L) projects that were introduced into existing courses. The reform began in 2005 and now includes S-L projects in required courses in each of the four years of the programs. Students have worked with community partners (e.g. Vermont towns and non-profit organizations) on inquiry-based, open-ended, real-world S-L projects. Student work and assessments showed that the S-L projects provided ideal platforms for CEE undergraduate students to grasp systems concepts while accomplishing academic goals, civic engagement and improving personal/interpersonal skills. The S-L projects also contributed toward meeting the program accreditation criteria (ABET outcomes 3a-k).

Keywords: community partnership; service learning; systems approach; capstone design; inquiry-based learning; ABET; assessment

D. Camacho, E. Pulido, M. D. R-Moreno, R. M. Carro, A. Ortigosa and J. Bravo 1270–1282 Automatic Course Redesign: Global vs. Individual Adaptation

The current state of educational technologies allows the design of a new kind of tools and frameworks that can use well known Artificial Intelligence (AI) techniques, such as Planning and Scheduling, to improve some aspects of the educational process. The quality of virtual education courses can be improved by automatically detecting flaws and providing alternatives, or solutions, to the educational designers. Nowadays, most educational platforms are designed to aid educators in both designing the course contents and controlling interactions with students. We propose a new AI-based approach that could be used by educators to monitor, measure and detect problems in their deployed courses. We describe the main issues related to AI techniques and e-Learning technologies, and how Longlife Learning processes and problems can be represented, detected and managed by using an integration of planning and scheduling techniques.

Keywords: adaptive educational hypermedia; artificial intelligence; planning & scheduling; lifelong monitoring processes

J. Uziak and M. T. Oladiran 1283–1291 Introduction of General Education Courses to Engineering Programmes at the University of Botswana

Complementary studies are fundamental for accreditation of engineering programmes in line with the Washington Accord. This paper presents the experiences of the University of Botswana in introducing General Education Courses (GECs) for the purpose of broadening the educational experience of all students, with particular reference to engineering students. Students registration data captured in the Integrated Tertiary Software (ITS) were analysed using Excel software. The five-year study period was from 2002 to 2007. Results indicate that engineering students mainly took GECs offered by the science and technology disciplines. It is concluded that GECs should be retained within the engineering programmes but the student advisory system should be improved and skills (e.g. IT competencies) that are important for professional development should be embedded in core courses instead of in general education.

Keywords: complementary studies; general education; engineering curriculum; accreditation

D. E. Jansen and Z. J. Pudlowski 1292–1297 Global Engineers: Creating Needed Solutions Through Intercultural Competence

Continued population growth, increasing industrialisation and the resulting need for ever increasing energy and food stock supplies lead to the huge challenges that mankind is facing. These challenges are both social and technical in nature. The causes and effects of these challenges are crossing continents and are by no means limited by national borders. As a consequence, national efforts alone will not be enough to tackle these challenges. Instead multi-cultural project teams will need to become more prominent. In order to successfully communicate and work in these teams engineers need to have intercultural competence. This paper describes the personal traits that enhance the acquisition of intercultural competence. It explains the important underlying concepts that should be taught to engineers in order to facilitate the acquisition of intercultural competence. It then goes on to suggest suitable training methods and a possible framework within university education to convey the recommended contents.

Keywords: intercultural communication; communication skills; multi-cultural project teams; global community; human relations skills