

# The International Journal of Engineering Education

## Contents

### Part I

- P. Shiue and T. Kurfess** 677 Guest Editorial
- G. Gary Wang** 678–689 Bringing Games into the Classroom in Teaching Quality Control

*The increasing pressures from students, industry, government, and accreditation organizations demand a paradigm shift in engineering education to turn the focus of education from instruction to learning. In the course of Quality Control at the University of Manitoba, the concepts and principles of Total Quality Management (TQM) are usually taught through a series of lectures. Given the fact that few of the students have had any industrial experience, traditional lectures on this topic tend to be boring and ineffective. This work developed a game approach to simulate the dynamics between the customer and competitive manufacturing companies. Students were divided into one customer group and a few competitive manufacturing groups/companies producing maple leaf bookmarks. By role-taking and game playing, students gain a quick appreciation of four of the six main TQM concepts, i.e., management commitment, customer satisfaction, action of all, and continuous improvement. Based on students' feedback, this approach was proved to be effective in teaching abstract concepts and in giving students a certain level of real-world experience. The specific game designed in this work might be tailored for teaching other industrial engineering and manufacturing courses. The game method, as a general approach, might be further studied and developed for engineering education.*

- Larry Whitman, Don Malzahn, Vis Madhavan, Gamal Weheba and Krishna Krishnan** 690–702 Virtual Reality Case Study throughout the Curriculum to Address Competency Gaps

*While most instruction aims to provide students with content knowledge accompanied by practical application, the classroom experience typically has difficulty providing students with non-trivial examples. Graduating students also express a lack of confidence in integrating knowledge gained in disparate courses regarding identifying problems and synthesizing solutions. Many programs include industry-based projects as a solution to these issues. This approach has various drawbacks, including the difficulty of implementing such a project in a sizable number of the courses, the need for a significant commitment of class time, establishing contacts and ensuring that students have sufficient access to them to develop a model. The Industrial and Manufacturing Engineering Department at Wichita State University is developing an integrated set of realistic virtual reality models of a manufacturing line at Boeing Wichita. This line and the virtual models will serve as a mega-case that will be used throughout the curriculum to vertically integrate the concepts across the curriculum and provide a situated learning experience for students. This large-scale virtual reality factory module, 'Innovation in Aircraft Manufacturing through System-Wide Virtual Reality Models and Curriculum Integration', is funded by the National Science Foundation through the Partnerships for Innovation program. The virtual reality models being developed include a Quest discrete-event simulation model of the 767 strut torque box manufacturing line and work cell level models in IGRIP and Jack software applications. Virtual Reality Markup Language (VRML) 2.0 files are generated from these models for use in case studies in various classes in the curriculum. Further details are available on the website (<http://www.slvr.org>). This paper recounts the gaps identified by the Society of Manufacturing Engineers and from surveys of our graduating seniors. A matrix that maps our plan to bridge some of these gaps in courses in the curriculum is presented. The use of virtual reality in general, and specifically in the classroom, is then discussed. The primary pedagogical approach used, situated learning, which places the learner at the center of the instructional process, is presented. Examples of course modules are then discussed to show practical applications of using the mega-case to bridge the gaps in manufacturing engineering education. A rubric developed for assessment of the critical elements required for an effective situated learning experience and the realization of these characteristics in the VR modules is presented. Lastly, the benefits and problems of this approach are discussed.*

- Laura R. Ray, Paula M. Berg and Kevin Baron** 703–712 Design and Manufacturing Education through Re-engineering Products

*Integrated design and manufacturing using rapid prototyping, polymer processing, casting, and automated inspection can revolutionize product design and manufacturing, particularly of labor-intensive and costly low-volume, high-end parts. To infuse manufacturing industries with new practices, engineering education in these areas should target laboratory experiences that stretch the student's imagination regarding how such processes can be used. This paper describes design and manufacturing laboratories based on product re-engineering that form the core of a studio-based computer-aided design and manufacturing course. Outcomes of classroom use of these laboratories are summarized. The course integrates design, engineering analysis, and manufacturing, provides hands-on experience with molding and CNC manufacturing processes, incorporates rapid prototyping within the design process, and provides experience with state-of-the-art metrology.*

- Peter Ball and Helyn Thornbury** 713–725 A Student Learning Environment without the Overhead? Reviewing Costs and Benefits of CAL within a Manufacturing Course

*This paper begins with a brief discussion of the current drivers within higher education and their impact and influence on the learning process. The requirements for an effective infrastructure at the class level are described, with specific links made to the use of computer-aided learning/assessment, effectiveness and efficiency. The paper goes on to describe the authors' experience of using Computer-Aided Learning (CAL) and Computer-Aided Assessment (CAA) in several linked classes over a number of years and to review them in terms of costs, benefits and efficiency.*

- Vincent H. Chan** 726–732 Learning CAD/CAM and CNC Machining through Mini-Car and Catapult Projects

*A new project was introduced in the fall of 2000 to second-year mechanical and industrial engineering students. The goal of the project was to reinforce the lectures in the areas of CAD/CAM software and its use for computer numeric controlled (CNC) machining. The project requires student teams to design from a common kit of stock materials. Experiences gained in the CNC machining lab taught the students the importance and the intricacies of machining. A student survey at the end of the project strongly suggested that this was a very effective way to learn about CAD/CAM and CNC machining.*

*Enterprise resources planning (ERP) is currently recognised as an effective manufacturing management information system that has an excellent planning and scheduling capability. It offers a dramatic increase in customer service, a significant gain in productivity, much higher inventory turns, and a greater reduction in material costs. Many manufacturing companies worldwide have attempted to implement ERP systems. However, there are various researchers who have reported failure cases; they identified training and learning of the ERP system is one of the major factors for the successful implementation of ERP. In this paper the authors attempt to overcome the lack of understanding and training of ERP in manufacturing industry. We propose an ERP training model which integrates with Web-based training to form the framework for training and learning. The model is simulated using System Dynamic—a powerful modeling and simulation methodology of Organization Learning and Training advocated by professor Forrester of MIT. The implementation of this model is described using an example from manufacturing industry. The results are illustrated with this lamp manufacturing company which indicated successful ERP implementation to achieve higher productivity and performances.*

**Zbigniew J. Pasek, Yoram Koren and Stephen Segall** 742–753 Manufacturing in a Global Context: A Graduate Course on Agile, Reconfigurable Manufacturing

*This paper describes the contents and organization of an advanced, graduate-level class which, while primarily focusing on principles of modern manufacturing, connects them with product design and business process issues, and places them in the context of two important trends: globalization and information-driven economy. The course aims to analyze the technical and business dimensions of various manufacturing paradigms, and identify concepts relevant to globalization and fragmented markets. It also emphasizes creativity in designing global products and touches on preparing simple business plans for starting new companies.*

**Debasish Dutta, Donald E. Geister and Gretar Tryggvason** 754–763 Introducing Hands-on Experiences in Design and Manufacturing Education

*ME250 (Introduction to Design and Manufacturing) is a core-course for undergraduates in the mechanical engineering department at the University of Michigan. It was introduced based upon recommendations from a review committee analyzing the mechanical engineering curriculum. This course is now a mainstay in the design/manufacturing sequence. We describe the objectives, philosophy, contents and teaching methods of ME250. It provides the mechanical engineering sophomores with a hands-on experience in design and manufacturing. The benefits of this course are now being felt in the curriculum, particularly in the capstone senior design projects course.*

**Timothy W. Simpson, D. J. Medeiros, Sanjay Joshi, Amine Lehtihet, Richard A. Wysk, Gregory R. Pierce and Thomas A. Litzinger** 764–776 IME Inc.—A New Course for Integrating Design, Manufacturing and Production into the Engineering Curriculum

*Senior capstone design courses and projects like the SAE Formula Car or Hybrid Electric Vehicle have been created to provide engineering students with 'real-world' and 'hands-on' design experience; however, the products being realized are often only working prototypes. Engineering students rarely have the opportunity to experience the entire product realization process, from designing a product to developing a manufacturing plan for it and subsequently producing it in volume. Consequently, we have developed a new two-semester undergraduate course, IME Inc., wherein multidisciplinary student teams design and develop a marketable product while considering all aspects of manufacturing—including process planning, tooling, assembly, outsourcing, and final costs—so that they can produce approximately 100 units in the Factory for Advanced Manufacturing Education. The objective in the course is to improve manufacturing engineering education by providing students with manufacturing and production experiences analogous to those obtained by journalism students working on a student-run newspaper. The course is taught jointly by five engineering faculty with expertise in product design, CAD/CAM, rapid prototyping, plastic injection molding, electronic assembly, and manufacturing systems design. Multidisciplinary teams consist of students in industrial and manufacturing engineering, students from other engineering disciplines (e.g. mechanical, electrical, and chemical engineering), and students from the business school studying marketing, management, finance, and accounting. The business students work directly with the engineers in analyzing product price, manufacturing costs, licensing issues, and developing a business plan and an e-commerce site to sell the products. Products designed, prototyped, and produced during the 2000 and 2001 offerings of IME Inc. are presented and discussed. Assessment strategies for evaluating team performance and the impact of the course on students' learning readiness are also presented. In particular, design notebooks and frequent design reviews are used throughout the course to monitor progress during design and production as well as evaluate team performance. To further enhance undergraduate education in manufacturing engineering, the course also focuses on creating a classroom environment that promotes self-directed learning, active and problem-based learning, teamwork, communication, and presentation skills. Individual learning essays are used to gauge students' understanding of the product realization process, while the impact of the course on students' lifelong learning abilities is assessed using the Self-Directed Learning Readiness Scale, a self-report questionnaire that is administered anonymously at the beginning and the end of the two-semester course. Lessons learned from the course are also discussed, along with plans for using IME Inc. as a 'living factory' to improve the broader industrial and manufacturing engineering curriculum.*

**L. Ken Lauderbaugh Saunders and Joan G. Saunders** 777–786 House of Quality Assessment of Business Skills Required by Manufacturing Engineering Graduates

*Continuing need for quality improvements and stronger connections between educational institutions and their stakeholders (customers) are moving institutions to explore novel assessment tools and curriculum design methods. These assessment tools need to focus on specific institution goals and specific groups of stakeholders. This presents a very different problem than that addressed in the broad questions and surveys that look at larger educational issues. This paper presents an assessment tool based on the House of Quality (HOQ) approach. The tool is used to assess the business skills required by manufacturing engineering graduates for a northeastern regional university. Specific results from this study are presented as well as a general formulation of the assessment method.*

**Akshay Kumar and Ashraf W. Labib** 787–800 Applying Quality Function Deployment for the Design of a Next-Generation Manufacturing Simulation Game

*Simulation games have grown in use as a training and education tool over the last fifty years. This paper examines the requirements of next-generation manufacturing methods and ascertains target design values for a novel simulation game that illustrates issues of next-generation manufacturing. Quality function deployment (QFD) is a powerful tool for translating customer requirements into target design values of engineering characteristics. This paper uses QFD to obtain design parameters for the novel game. Identified key paradigm and system elements of next generation manufacturing are used as the customer requirements or 'Whats' in the QFD analysis. Engineering characteristics of games are used as the 'Hows'. Linear regression and multi-attribute value theory with linear programming is used to translate the voice of the customer into optimum target design characteristics.*

## Part II

**Zhiqiang (Eric) Liu and Dieter J. Schönwetter** 801–808 Teaching Creativity in Engineering

*Creativity education in engineering is an ongoing critical issue for universities, in the sense that it helps meet the expectations for professional engineers, as well as completes the intellectual development of individuals. However, the importance of implementing*

creativity education in the classroom has not been fully recognized. In this paper we reviewed recent publications in this regard, attempting to dissect what creativity means to engineers, and how they can overcome the blocks to creativity. Having comprehensively explored the creative process, we suggested an operable tool based on Treffinger's creative learning model that can be implemented in a classroom setting to facilitate creativity.

**Francisco Ruiz** 809–819 Learning Engineering as Art: An Invention Center

This article describes a class where engineering students develop potentially patentable commercial products in a studio setting. Students work on two individual projects, with prototypes, patent description, and a small business plan within one semester. The first long-term survey of participating students indicated that the greatest impact of this class was on their understanding of real-world situations, and their ability to come up with creative ideas. Some positive commercialization results have occurred with nearly one fourth of the students participating. The emphasis of the article is on the pedagogical methods involved in this kind of course, although some assessment results are also included.

**D. A. Barry, D. S. Jeng, R. B. Wardlaw, M. Crapper and S. D. Smith** 820–833 A Robust Grade Adjustment Procedure

Assurance of equity in student outcomes includes ensuring that module results are comparable within reasonable bounds. We present a procedure that first compares (and adjusts if necessary) module variances. Then, student results are individually normalised to standard variates. A simple sign test is used to identify modules with disproportionately good or poor results. Module results are offset so as to adjust averages that do deviate. A detailed examination of an artificial data set shows that the proposed very simple procedure yields results that agree with a sophisticated statistical analysis.

**A. Atrens, R. W. Truss, A. Dahle, G. B. Schaffer, D. H. St John, C. Cáceres and J. D. Gates** 834–848 Graduate Attributes in Relation to Curriculum Design and Delivery in a Bachelor of Materials Engineering Programme

This paper presents a critical analysis of the Bachelor of Materials Engineering programme compared with the expectations of the Institution of Engineers Australia (IEAust) and of UQ. To set the scene, the graduate attributes are listed, the programme framework is presented and the educational culture and available facilities are described. Then, the programme delivery is described; this includes an analysis of the learning opportunities that allow students to develop the graduate attributes. Finally, an assessment is made of programme outcomes relating to graduate attributes.

**T. Özer and E. G. Cravalho** 849–860 On Developments in Interactive Web-based Learning Modules in a Thermal-Fluids Engineering Course: Part II

In this paper we present the general features of the project known as I-Campus, developed for enhancing the traditional lecture format in subject 2.005 Thermal-Fluids Engineering I, a core second-year subject in the Mechanical Engineering curriculum at the Massachusetts Institute of Technology (MIT). This new methodology utilizes computer-based teaching and learning models. We also introduce the pedagogical basis for the study and then present the details of the fundamental characteristics of the study together with the new learning technologies derived from them. We then illustrate the manner in which we have incorporated these new materials of the study.

**Sherri Johnston** 861–866 A University Project to Produce an Analogue Robot Kit for Schools: Do Customer-based Projects Affect Student Motivation?

The study presented in this paper explores the effect of modifying a robot design, build and test project to motivate the students to adopt a deep learning approach. This was achieved by changing the end product to a robot kit, which was used to teach year 9 school pupils about analogue electronics. The results showed that the students were motivated towards a deep learning approach by different factors. In this study, three factors were identified. A second part of the project involved the students teaching year 9 pupils using the robot kits. The indications were that this had a favourable outcome.

**Ali El-Hajj, Karim Y. Kabalan and Shahwan Khoury** 867–871 The Use of Spreadsheets to Calculate the Convolution Sum of Two Finite Sequences

This paper presents an educational spreadsheet programs for calculating the convolution sum of two finite sequences. This convolution sum is accomplished using three different methods. After each method is presented, the procedure for computing the convolution sum is outlined, and the results are obtained for each of these cases. These explicit methods of calculation are proven to be well suited for an educational environment as characterized by their flexibility and simplicity. Moreover, when such software is used, they could make engineering studies more appealing to the students.

**Laureano Jiménez, Josep Bonet and Carles Coscolluela** 872–878 Production and Separation of Ethanol: A Didactic Experiment

In the laboratory we use didactic experiments to consolidate and integrate the knowledge that students receive in theoretical classes. We present a procedure based on the batch fermentation of glucose, followed by a solid-liquid separation and the subsequent distillation to obtain high purity ethanol. The organisation and operation of the laboratory is such that students have to formulate hypotheses, search for information, conduct experiments, extract conclusions and determine the best set of operating parameters. Moreover, we pose open-ended questions to force students to develop their social abilities, and address important topics of the hidden curriculum (environmental, legal regulations, safety, etc.).

**A. Kutlu** 879–885 MicroLab: A Web-based Multi-user Remote Microcontroller Laboratory for Engineering Education

This paper discusses the implementation of a Web-based multi-user remote microcontroller laboratory designed for electric-electronic engineering education. The MicroLab has been developed to provide programming and monitoring microcontroller modules through the Internet for undergraduate students. Students can access the MicroLab individually and simultaneously. The MicroLab consists of a server with web cams and microcontroller modules which have 8051 core architecture, and are equipped with a CAN (Control Area Network) as its peripheral architecture.

**Isaac Elishakoff** 886–890 A Material that Ought to find its Place in Future Strength of Materials Textbooks

A material is exposed that appears to be appropriate for the future strength of materials textbooks. The described solution is simpler than the classical solution by Euler derived over 250 years ago. The material, although elementary in mathematical terms, represents a simple example of a semi-inverse design problem and leads to the closed-form solution. The material can be covered within 2 lecture hours of 50 minutes duration each.