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Special Issue
Design and Engineering Education in a Flat World

Guest Editor
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This paper encompasses and extends remarks made at the opening of a workshop on engineering and design education in a flat world by the workshop's organizing committee's chair. Held at Harvey Mudd College in May 2007, and supported by Mudd's Center for Design Education, Mudd Design Workshop VI brought together engineers and designers—in their roles as educators, researchers and practitioners interested in learning and in design—to identify and articulate important flat world issues in design and engineering education. The remarks detailed below were intended to highlight some of the issues that arise due to globalization and a developing flat world, as well as to raise some questions about what engineering educators might do that could be addressed by the workshop's presentations and discussions. While some aspects of these remarks may well have been in the vein of preaching to the converted about issues of design teaching, it is also noted herein that the many benefits associated with teaching design—which are increasingly seen as meeting many of the primary goals of engineering education—are equally relevant—if not more so—in the context of engineering education in a flat world.

Keywords: design pedagogy; design practice; globalization; flat world; design research

Assessing Flat World Skills

Little doubt exists that globalization will be a dominant part of engineering in the twenty-first century. This major shift—from engineers collaborating and competing within a fairly limited region to engineers collaborating and competing around the world—will require engineers to possess different knowledge to be successful. Two areas of design knowledge that are becoming more important due to globalization are problem definition and idea generation. These areas of knowledge are cited as being important because they rely on 'right-brain' thinking in addition to analytical know-how, a combination that is more difficult to offshore. In this study, knowledge of the roles of problem definition and idea generation in engineering design is assessed over time: subjects are assessed before any college-level engineering, during their engineering education, and five or more years after starting to practice engineering. The primary assessment instrument involves subjects critiquing a proposed design process; their critiques are then analysed to determine what they know about the roles of problem definition and idea generation in design. Results show that no significant learning about problem definition occurs until an undergraduate's senior year, with large gains also made after graduation by practicing engineers. For idea generation, students learn a significant amount while enrolled in an introduction to engineering course, but lose this knowledge later during the curriculum.

Keywords: Engineering design; engineering education; global economy; problem definition; idea generation

In this paper we characterize breadth of problem scoping in an engineering design problem. Specifically, we present several measures that quantify the number and variety of factors an individual problem-solver considers during the engineering design process. We apply these measures to data collected from freshman and senior engineering students who solved a short design problem. The results of our study indicate that graduating seniors do consider a broader array of factors than freshmen as they undertake the problem-scoping stage of the design process.

Keywords: design; problem scoping; breadth; context; engineering design task; undergraduate; engineering education research

Through descriptive data of students' design processes at the beginning and end of an engineering programme, we provide insights into questions of: what changes do we see in individual engineering students design processes over the course and how might these design process changes prepare students to become 'the global engineer'?

Keywords: design; problem scoping; change; engineering design task; undergraduate; engineering education research; verbal protocol analysis; case studies; personas

A new design education model has been developed to address the issue of technical depth in undergraduate design education by utilizing graduate students as coaches. This model has been implemented in a junior-level capstone materials science and engineering design course. The model allows the graduate student coaches to experience supervision of other researchers while serving as a technical resource and role model for the undergraduate design team. Meanwhile, the instructor serves as an expert who oversees the instruction of the course and the graduate student coaches. With reduced responsibility, the instructor can focus on the quality of research performed while influencing a greater number of design teams. This paper provides an overview of the model, its characteristics and execution, and presents findings from interviews with the graduate students coaches and undergraduate design team members. Results from our study suggest that the model provides benefits for all participants in the hierarchy.

Keywords: Engineering design; coaching; design education; pedagogical strategy

Flat World Teaching and Design Tools

Learning engineering nowadays requires acquiring the necessary skills to remain competitive in an increasingly flat world, as well as the ability to deal with practical problems using edge technology. Modern learning techniques attempt to compensate some of the shortcomings suffered by more traditional approaches, by including real-life industrial problems in the academic environment. The main contribution of this paper is to explore a Collaborative Learning Method to achieve the integration of learning techniques, Product Life-Cycle Management (PLM) and collaborative tools to tackle projects for the automotive industry. The method is implemented and validated via a case study on design engineering.

Keywords: Collaborative method; POL; manufacturing; PLM tools; collaborative tools

We believe that two critical success factors for an engineer in the flat world are an ability to adapt to changes and to be able to work at the interface of different disciplines. Instead of educating traditional domain-specific and analysis-orientated engineers, we believe that the focus should be on educating and graduating strategic engineers who can realize complex systems for changing markets in a collaborative, globally distributed environment. We identify three key drivers that we believe are foundational to future engineering design education programs. These drivers are a) emphasis on strategic engineering, b) mass customization of courses, c) utilization of IT-enabled environments for distributed education. Strategic engineering is a field that relates to the design and creation of complex systems that are adaptable to changes. Mass customization of courses refers to adapting the course material to educational goals and learning styles of different students. IT enabled environments bring distributed students and instructors closer in the form of a virtual classroom.

Keywords: strategic engineers; mass customization of education; distributed education; flat world; product creation

In our increasingly flat and connected world, skills in innovation and creative design have emerged as key attributes for graduating engineering designers. Metaphors and analogies are commonly voiced as key tools for enhancing creative design yet little research has been performed on their relation to each other and their use within the design process. In this paper we discuss the relationship between metaphor and analogy use in the design process, with a focus on engineering education. We support our discussion with results from interviews and experiments with student designers. Our results highlight that both metaphor and analogy are spontaneously used by student designers and that metaphor dominates as the design tool for early problem-framing design phases whereas analogy dominates as a tool for concept generation. We also present an analysis of the metaphors for our understanding of design in use within Germany, the UK and Mexico. We found an 85 per cent overlap between textbook usages of metaphors in conceptual design in these countries as compared to textbooks authored in the United States, suggesting that cross-cultural differences in design understanding are relatively small in higher education. We close by presenting a design by analogy method to promote and enhance the use of analogy as a skill for graduating engineering designers.

Keywords: metaphor; analogy; creative design; idea generation; innovation processes; problem framing; design methods; design thinking; design education

Cross Cultural Considerations

This paper presents our preliminary exploration of differences in design thinking patterns due to cultural differences. While our ultimate goal is to seek empirical evidence for how culture impacts on the design process and design outcomes (the artifacts), in this study we focus on the attention paid to objects versus contexts by a group of Eastern and Western designers. Our work is informed by the recent findings in social psychology regarding the covariance of persisting social differences and cognitive processes.

Keywords: engineering design; cultural differences

The ABET EC 2000 criterion requiring that engineering graduates 'understand engineering solutions in global and societal context' has proved problematic to address, because most engineering faculty are neither trained in, nor enthusiastic about including, topics which are logically part of the larger view required of 'global and societal context'. We present here our experience in providing 'engineering solutions' in broader contexts, achieved through integration of lecture or laboratory in technology into a foreign language course. We have offered such integrations in three formats: (i) Technology cameos in English, set in a Spanish language course, (ii) Technology cameos in French, set in a French language course, and (iii) Device dissection lab activities executed as part of a Spanish course. We demonstrate that engineering/foreign language faculty collaboration within such integrated courses formats provides one potential path to introducing 'engineering solutions in global and societal contexts'.

Keywords: Societal context; foreign language; engineering solutions

Nearly every code of professional ethics used in engineering begins with an affirmation of the engineer's obligation to hold paramount the safety, health and welfare of the public in the performance of professional duties. Most of these also either explicitly or implicitly acknowledge that the achievement of these high standards depends on the judgments made by practitioners in designing structures, devices, systems and technologies. To date, almost all of the interpretation and analysis of this first canon has focused on situations in which an ethical failure will result in an immediate catastrophe such as a building's collapse or loss of lives, that is, on the safety and health terms. Indeed, very little attention has been given to the 'welfare of the public' aspect of the code. While the meaning of this key phrase is often presented as self-evident, the current approach to the principle often relieves engineers of the responsibility to engage actively in articulating their design choices with the full substance of the ethical commitment it entails. Engineering ethics demands that, as part of their professional practice, they ask themselves (and others): what is the public welfare and how might my design choices either serve or undermine it? This paper asks what it would mean for engineers to live up to a demanding interpretation of this fundamental ethical commitment, and explores the contribution engineering education might make to enabling them to do so.

Keywords: ethics; politics; technology and society; engineering education

Virtual collaborative engineering and design in a flat world relies upon the ability of distributed teams to perform as an integrated unit. Present research analyses how geographical dispersion and cross-cultural issues influence team performance when working under a collaborative engineering strategy. Its main contribution is to establish a common set of effective design practices for practitioners of design involved in new product development. Educators and students from Tecnologico de Monterrey in México, Virginia Tech & Howard University in the USA, Darmstadt University in Germany and Shanghai Jiao Tong University in China conducted this work. These universities are collaborating in the 'Partners for the Advancement of Collaborative Engineering Education' programme (PACE). The results come from design teams at ITESM and reflect a semester's worth of work. The students were enrolled in the senior year of the mechanical and industrial design engineering programmes and had previous experience related to the use of communication tools and CAD systems. The Nominal Group Technique (NGT) was applied to obtain multiple inputs from all persons involved in the project.

Keywords: cross-cultural issues; nominal group technique; collaborative engineering; collaborative design; globally dispersed design teams

International Curricula

This paper describes the focus area of the MIT-Portugal Programme that deals with Engineering Design and Advanced Manufacturing (EDAM). The EDAM initiative consists of two new post tertiary degree programmes plus affiliated research and industrial liaisons. The paper also discusses the Portuguese innovation and education trajectory and the challenges felt by Portugal as the world becomes more networked (or flat). Some quantitative statistical studies of Portuguese innovation and education metrics are examined to explore the needs for new initiatives such as the MIT-Portugal Programme.

Keywords: global connectivity; technology policy; Portugal; MIT; R&D development

Engineering education is one of the key factors for the development of any nation. Nowhere is this more true than in Sub-Saharan Africa, where a dearth of engineers has contributed to the lowest regional standard of living of anywhere in the world. The need in this region is so vast and immediate that it could only be met by the use of ICT-based education. This paper presents the findings of an investigation into the feasibility of providing tertiary level engineering education through current information and communication technologies in Sub-Saharan Africa. Data collected include an extensive review of the available literature, contact with current providers of ICT-based engineering education, and a survey of 250 engineering firms in Sub-Saharan Africa, the end-users of engineering education in that region. The findings indicate that it is indeed feasible to deliver tertiary level engineering education to Sub-Saharan Africa, assuming that resources could be found for course development and to enhance the technological capacity of local institutions. This paper complements the picture of a 'flat world' drawn by Thomas L. Friedman who in his recent book focused on well-developed countries only.

Keywords: Information technology; distance learning; tertiary engineering education; Africa; Third world

This paper discusses lessons learned from an innovative course—Product Realization for Global Opportunities—first offered in Spring 2007 at the University of Pittsburgh. Its purpose was to further infuse both sustainability and product realization into the undergraduate engineering curriculum. We have done this by creating a unique product realization course in which E-teams of students from University of Pittsburgh and the University at Campinas (UNICAMP) in Brazil attempt to develop products for sustainable human development. In particular, the course addresses the product realization process in the context of sustainability for the developing world. In doing this, we have taken advantage of the School of Engineering's rapidly expanding interest in sustainability led by the Mascaro Sustainability Initiative (MSI), a growing relationship with UNICAMP, and close involvement from the University's International Business Center and the Center for Latin American Studies (both Department of Education Title VI National Resource Centers). Further, students use our Swanson Institute for Product Innovation to develop prototypes. Course development was supported by a programme grant from the National Collegiate Inventors and Innovators Alliance (NCIIA). This paper presents findings from surveys conducted at the end of the course including an entrepreneurship questionnaire developed by the National Collegiate Inventors and Innovators Alliance (NCIIA). The course produced significant increases in students' self-perceptions of skills needed to become an entrepreneur and in financial dimensions of entrepreneurship as well as idea generation, product pricing, and intellectual property concerns.

Keywords: Product realization; international programmes; design for human development; sustainable design; global issues in engineering

The pedagogy of project-based courses is notoriously difficult to transfer but in today's global economy it is crucial to be able to teach innovation. Therefore, an experiment was performed to evaluate how a design innovation course could be transferred across cultures, disciplines and institutions. Specifically, a graduate level engineering design course from Stanford University was emulated at the University of St Gallen in Switzerland. The course methodology exemplifies the innovation approach taken by notable companies that represent the innovation success of Silicon Valley. The results obtained from a series of interviews indicate that there is a set of essentials to this pedagogy, which, when transferred, led to similar innovation success elsewhere.

Keywords: Project-based learning; design education; design thinking; pedagogy; innovation; education; failure; iteration; motivation; team formation; coaching; transferability autonomous learning

This paper describes two case studies where immersive 'experiencing' of a novel concept led to a better understanding of it. This approach helped bridge cultural and academic divides. By having a shared experience, the members of a multi-disciplinary, distributed project aimed at poverty alleviation created shared meaning. The creating and experiencing of prototypes proved to be a transformative experience. These cases suggest the engineering students, who are increasingly working on design projects in developing countries and other culturally unfamiliar situations, would benefit from learning to undertake such immersive experiencing as part of how they approach design. This argument is made in the context of John Dewey's model of 'active doing and undergoing'.

Keywords: prototyping; poverty alleviation; multi-disciplinary distributed teams

This paper summarizes and highlights the presentations and discussions that took place during a workshop on engineering and design education in a flat world. Mudd Design Workshop VI (MDW VI) was held at Harvey Mudd College in May 2007, and supported by Mudd's Center for Design Education. This article endeavours to capture the spirit of the participating engineers and designers who worked to identify and articulate important flat world issues in design and engineering education, as viewed in their everyday roles as educators, researchers and practitioners.

Keywords: Design education; design practice; globalization; flat world; design research