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Part 1

system. The analysis is framed to address the implementation potential of ideas for how educators might efficiently teach undergraduate engineers 'that engineering is more than differential equations'. The concepts which seem best from this analysis are combinations of aggressive intern opportunities combined with courses (starting in the freshman year) that emphasize the creative engineering process. These activities may be containable in the four-year program but the analysis also suggests that extension of engineering education to three or more years beyond the B.Sc. would improve the possibility of reaching key educational goals including teaching adequate math and science fundamentals as well as engineering knowledge, process and creativity. Such radical change will be difficult and slow to occur (if at all) in this complex system. Moreover, this system is understandably resistant to change because of significant perceptions of outstanding achievement. The driving force for change that may be strong enough to overcome these barriers is prospective students' falling perceptions of engineering education as a preferred option.

The purpose of this paper is to discuss some of the steps that we within the broader technical community (industry, government and academe) can and should take to assure an adequate future supply of well-prepared engineering graduates for the full range of employers who have need for such talent. While presented from an aerospace industry perspective, and thus from that of a 'mature industry' (at least in some major traditional product areas), it is believed that the issues to be addressed have far wider relevance, because the evolution of engineering (and specifically design) practice in the 'airplane business' provides a lens for discerning future trends and requirements for both university and post-employment engineering education programs. Although much has been accomplished in the past decade to enhance engineering education, we, as both educators and practitioners, have much to do to cooperatively create a strong and vivid vision of our future and assure the proper development of a future generation of engineers with the skills and motivation to meet society's needs in our always evolving and ever-volatile enterprise.

Motivating Student Learning and Growth

One approach to addressing the dilemma of poor mathematics and science performance of US students on standardized tests and lagging enrollment in US engineering colleges is engineering outreach to the K-12 community. Engineering outreach has been a core mission of the Integrated Teaching and Learning (ITL) program since its inception. Team-based design spans the entire K-16 hands-on learning curriculum, integrating math and science fundamentals through creative, self-directed learning. Experiencing design provides a context for undergraduates to develop advanced technical skills, and motivates youngsters to pursue an engineering path. This paper describes how design pervades the diverse ITL K-16 spectrum, including a variety of engineering curricula for K-12 students, as well as undergraduate engineering courses.

Our goal is to promote a research-informed approach to engineering design education. Over the past eight years, we have conducted a number of studies in order to understand how engineering students do design. Some of our current efforts focus on integrating research and practice in engineering design education. Because of the complexity of real educational practice, we are working on multiple strategies to bridge the research-to-teaching gap. These include: 1) the creation of instructional activities based on our research results and 2) a workshop model to engage design educators with research on engineering student design behavior. In this paper, we present a framework for thinking about the link between research and teaching, provide detailed descriptions of the two strategies mentioned above, and discuss the effectiveness, viability, and reproducibility of these strategies.

We 'create' a basis set for construction of new multidisciplinary design (MDD) courses and projects by the decomposition of the many examples of such activities within the SUCCEED coalition. The development of such a 'basis set' for this new area of engineering education allows engineering faculty and their non-engineering faculty and professional colleagues to create new versions of MDD experiences which can be conveniently integrated into the local campus needs and engineering school mission.

New Designs for Engineering Education

Aeronautics in its traditional form is usually presumed to have started as a formal engineering discipline somewhere in historical time between the mythological experiments of Daedalus and his ill-fated son Icarus, and the dreams and schemes of Leonardo da Vinci during the Italian Renaissance. As is briefly reviewed in this presentation, 'aeronautics' has a far longer (though less disciplined) history extending over a period of about 300 million years, beginning with the evolution of the ability of insects to fly. With the advent of the success of the Wright brothers, technologists quickly turned their attention from the inspirations and lessons provided by natural models of flying machines to a more practical quest for increasingly dramatic improvements in speed, range and altitude performance far beyond the limits of what muscles and flapping wings could provide. Thus a field of further productive inquiry was left to a few amateur aeronauts, eccentrics and biologists. A purpose of this paper is to remind both the biomechanics and engineering communities of what has transpired during almost a century of advance in both fields of knowledge, and what is still being discovered in the light of great progress in computational and testing technology. A more important purpose is to demonstrate some of the numerous very rich sources of inspiration and motivation such multi-disciplinary explorations offer both the engineering practitioner and educator.

This paper introduces IDEA—the Institute for Design Engineering and Applications. IDEA brings together a number of Northwestern University's existing undergraduate and graduate programs in engineering design and introduces two new programs: 1) a Certificate in Engineering Design that may be earned by any engineering undergraduate; and 2) a Bachelor's in Manufacturing and Design Engineering. We review a number of our guiding philosophies and give an overview of the two new programs.

There is a national crisis in engineering and a compelling need to reconsider and rejuvenate engineering education. Shortcomings in engineering education have been identified by the National Academy of Engineering, the National Research Council and the National Science Foundation, among others, and are marked by an extremely narrow approach to education, inadequate preparation of engineers to function in multidisciplinary contexts, and practices that are exclusionary to women and under-represented minorities. These symptoms of a less than optimal education system underscore the pressing need for the realignment of engineering education. The Picker Engineering Program at Smith College is at the forefront of change in engineering education, as the first institution to establish an engineering program at a women's college, the first institution to establish a faculty position with a dual appointment in engineering and education and the first institution with an engineering faculty that is more than 50% women. The Picker Engineering Program promotes engineering as a liberal art and as a profession in service to humanity. We believe that both these tenets are vital not only to the success of the program but also to the engineering profession and the comprehensive education of our youth. Smith College hopes to

students developed a strong belief that 'good design' dictates that technology can and should serve all members of the potential user population, including those traditionally under-represented in technology. Finally, students showed an increased level of confidence in technology and an increased comfort level working on design projects.

Technology is human behavior that transforms society and transforms the environment. Design is the cornerstone of technology. It is how we solve our problems, fulfill our needs, shape our world, change the future, and create new problems. From extraction to disposal in the life-cycle of a product, the design process is where we make the most important decisions; the decisions that determine most of the final product cost, and the decisions that determine most of the ethical costs and benefits. It is quintessentially an ethical process. Ethics is not an appendage to design but an integral part of it, and we advocate using the moral imagination to draw out the ethical implications of a design [1]. We will stress and develop the social ethics paradigm, because design is an iterative social process for making technical and social decisions that may itself be designed at each stage with different people at the table, different information flows, different normative relationships, different authority structures, and different social and environmental considerations in mind [2]. Despite the considerable recent growth in the literature and teaching of engineering ethics, it is constrained unnecessarily by focusing primarily on individual ethics using virtue, deontological, and consequentialist ethical theories. In contrast, the social ethics method requires an examination of the social arrangements for making decisions that is particularly relevant to the iterative, decision-making, design process. Different social arrangements may be made for making any decision, each of which arrangement embodies different ethical considerations and implications. Dewey argued in much the same way for a scientific and experimental approach to ethics in general: 'What is needed is intelligent examination of the consequences that are actually effected by inherited institutions and customs, in order that there may be intelligent consideration of the ways in which they are to be intentionally modified in behalf of generation of different consequences.' [3]. The social ethics paradigm that we will unfold owes much to the pragmatist thought of John Dewey.

Summary Paper

This paper reports on the Mudd Design Workshop IV held at Harvey Mudd College (HMC) in July 2003 to discuss a broad variety of issues on engineering education. Sessions were devoted to: ABET's EC 2000; barriers to change; learning and motivation; the many roles of design; and the ethos of and ethics in both education and practice. Major emergent themes included: the need for engineers to educate the public and their policy-makers about the processes of engineering; that research into engineering learning must be conducted by (at least in part) and recognized by engineering faculty; that design can motivate and enhance the place of values and ethics in undergraduate curricula; and that positive change is emerging in engineering education, notwithstanding the formidable and enduring barriers to such change. Before leaving, participants converged on a set of goals that they would try to advance—both individually and collectively.

Part 2

Contributions on Engineering Education Policy, Visualisation, Assessment in Software Engineering, Engineering Mechanics, Electronic Engineering

Business is increasingly conducted in a global environment, not only in terms of markets but also design, production and service. It is therefore essential that engineering graduates have an orientation towards this globalization and are prepared to operate effectively within it. One manifestation of this new environment is the increasing need for engineers and others to collaborate internationally on projects, whether they are within the same international organization or in another relationship, such as with sub-contractors or between end customers and suppliers. Also in this context we are increasingly seeing the expression '24-hour engineering' used as business takes advantage of time zones around the world to effect efficient hand-off of a project between international teams. Significant challenges must be overcome as engineers learn to work in the international environment. These challenges include those associated with different cultures and languages as well as the problems associated with what has been termed 'virtual teams', which comprise physically separated individuals or groups that are connected through various communications links and information technology tools. This paper explores how industrial psychology and other literature from the business world can provide insights into the challenges and possible solutions that should be addressed in providing engineering students with an appropriate experience to prepare them for the new international teamwork paradigm. How this information can be used in implementing an effective program for international student project collaboration is also discussed.

In the fields of physical sciences and engineering, there are many difficult and abstract topics and phenomena. The student population entering engineering education programmes is becoming more and more heterogeneous. The incoming students often have little experience in technical applications and phenomena in physical sciences. They also have very diverse learning styles. In this day and age, when change is the norm, the demands on engineering educators are extensive. Students should be provided with various skills, such as communication, teamwork and learning skills, in addition to a good command of the subject matter. Visualisation aids the lecturer to meet the diversity of learning styles represented by engineering students and aids the students to attach meaning to concepts and phenomena. On the basis of retrospective reflection on their experiences as lecturers and educators in the field of engineering education and on the basis of two case studies, the authors present a concrete example of a method of utilising visualisation in the field of materials science dealing with metals. The authors also discuss the use of a PDEODE worksheet (Predict-Discuss-Explain-Observe-Discuss-Explain) in integrating lectures, demonstrations and lab work. The pedagogical background of the PDEODE worksheet is also dealt with.

This paper briefly explores the role of experiential learning in software engineering education, focusing on Problem-based learning. An existing assessment strategy for grading individual students in a small group Problem-based learning setting is described. Although the student grades obtained may be a reflection of the course success, and standard questionnaires are also employed to monitor student feedback, the authors devised a method to determine how the students themselves perceive the success of the course in terms of their own learning outcomes. As well as complementing the existing assessment strategy, this would allow them to evaluate the possibility of integrating student self-assessment into the overall assessment strategy and would act as a valuable feedback mechanism in fine-tuning the course. The results indicate that students perceive a marked increase in their knowledge as defined by the course curriculum. In addition, there is a significant difference between how course facilitators grade the students and how the students rate their own knowledge. Interestingly, no obvious correlation was found between the academic results of the students at the end of the previous year and their subsequent results in the Problem-based learning course.

In the study presented here, the problem of calculating deflections of curved beams is addressed. The curved beams are subjected to both bending and torsion at the same time. The Castigliano theorem, taught in many standard courses in Strength of Materials, Mechanics of Solids, and Mechanics of Materials, is used to determine the beam deflections. Using the methodology presented here, beam deflections that cannot be found in handbooks or textbooks can be calculated without too much effort. The Castigliano theorem and a numerical integration algorithm from the MATLAB package have been used. The examples investigated in this paper deal with elliptically curved beams. The beams are either statically determinate or statically indeterminate. Limiting cases of the elliptical beam are bending of straight beams and bending and torsion of a circular beam. Beam deflections obtained in the limiting cases are compared with handbook formulae.

Presented here is a simple circuit involving ideal operational amplifiers that we have not located in any standard electronics textbook. Analyzing it using standard methods leads to an indeterminacy that can only be resolved by re-examining the fundamental assumption of infinite gain associated with such amplifiers. A re-examination of standard assumptions in an altered context is always educational, in this case for undergraduate students of electronic circuits. A proposed use for this circuit as a reliability tool is also discussed, and its associated analysis is an instructive exercise in itself.