

The Art of Engineering in Capstone Design

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Abstract

It is the author's strong belief that engineering students should seek creative designs from arts as well as other perspectives to understand multidisciplinary design techniques and effectively solve today's complex design problems. In Spring 2003, senior design projects completed at the Purdue School of Engineering and Technology at IUPUI (Indiana University Purdue University Indianapolis) illustrated the results of a harmonious merger of the artistic and technical talents of our students. This paper presents information on a unique capstone design project that involved collaboration between the arts and engineering, and the impact on the quality of the final design. It is very likely that multidisciplinary design projects will be increasingly developed and implemented in institutions of higher learning across the country as more art and engineering collaborations lead to creative design projects and valuable learning experiences for students.

Introduction

The Accreditation Board for Engineering and Technology's (ABET) EC-2000 criteria emphasizes the need for design rich curriculum providing contemporary and real-world applications [1]. Over the years, engineering educators have been modifying and enhancing the design curriculum through a variety of means including advanced thinking skills, creative and inventive process and multidisciplinary projects and experience [2-5]. National organizations, like American Society for Engineering Education (ASEE) [6], National Science Foundation (NSF) [7], American Society of Mechanical Engineers (ASME) [8], and others have identified "Multidisciplinary Design" as an important topic in the mechanical engineering curriculum for undergraduate students. Multidisciplinary design is a vast topic, and it is very hard to find relevant material in one prescribed book. Also, faculty from various disciplines may have valuable experiences but not have the opportunity to engage in a collaborative teaching environment. We feel that there is a need to develop ways of integrating creative multidisciplinary teaching/learning techniques into the undergraduate curriculum.

The author has been teaching design courses as part of the ME curriculum at the Purdue School of Engineering and Technology at IUPUI (Indiana University - Purdue University at Indianapolis) for more than a decade. The design courses have undergone many changes over the years to reflect current theory and practice in the field. Engineering design courses are integrated into the ME curriculum, beginning with a basic introduction to mechanical design examples and background during the freshman year to advanced capstone design projects in the senior year. Recently, there is a growing interest in synthesizing innovation and creative processing in engineering curricula through art [9, 10]. Patton and Bannerot [10] discusses nicely the design principles and process from engineering and art perspective with respect to various aspects including invention and creation; beauty; and intellect and intuition. This paper discusses a unique capstone design project experience involving an art student along with ME students, and the resulting quality of the final design.

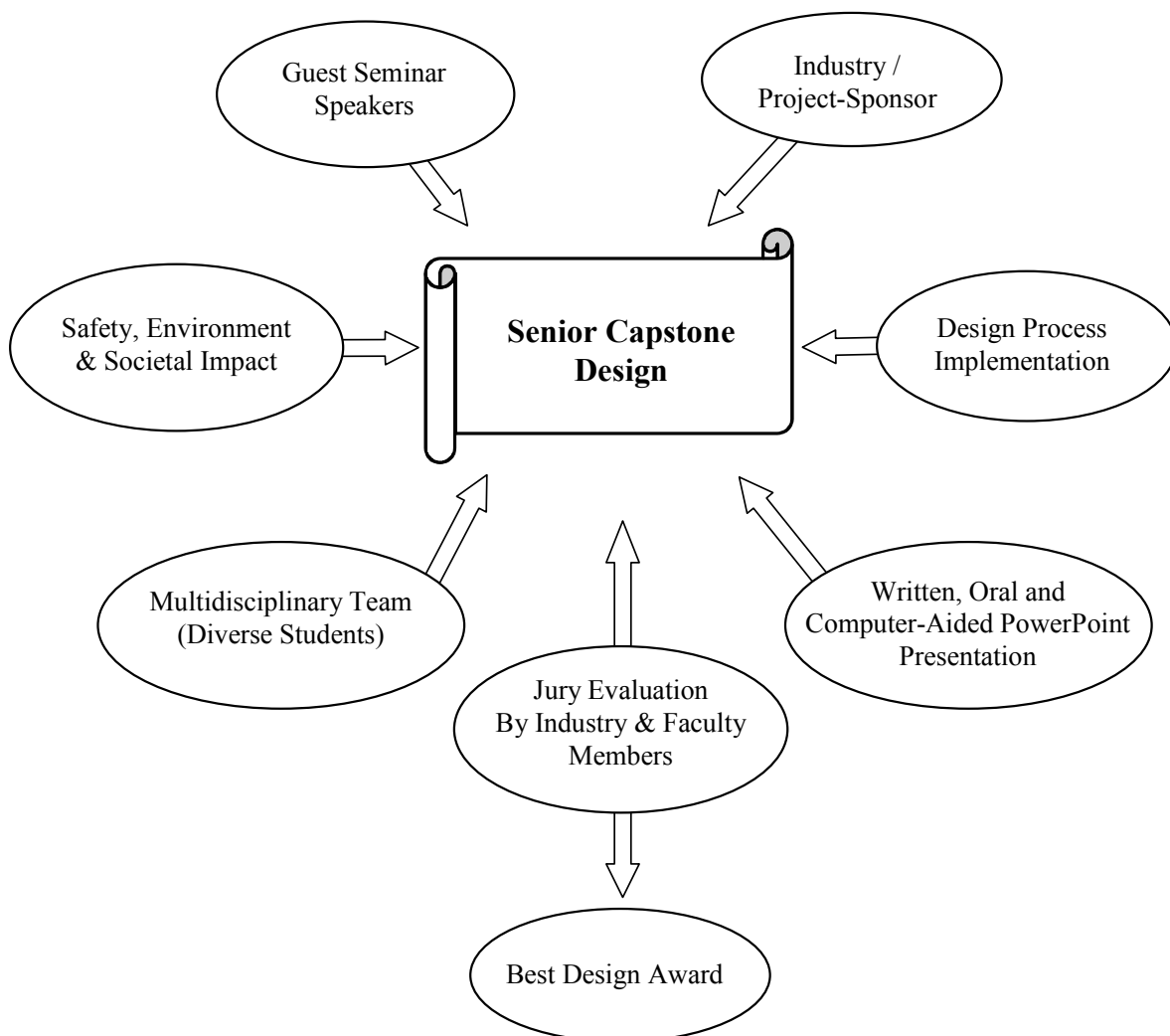


Figure 1. Overview of the Capstone Design Course emphasizing Multidisciplinary Aspects

Capstone Design Course Emphasizing Multidisciplinary Projects

The capstone design (ME 462) course builds on what students learned in the rest of the curriculum and requires them to implement the design process by working on an independent project sponsored by industry or faculty. The students are required to discuss safety, environmental issues, and societal impact of their designs in addition to ethics and professional responsibility, as part of ABET program outcomes [1]. Recently, a seminar component was added to the course where guest speakers from industry and faculty from various departments are invited to speak about such topics as professionalism, project management, green design and manufacturability, sustainability design, arts and bio-inspired designs, robust design, and specific design project experiences. As part of the course requirements, students in the capstone design project are required to write a brief report summarizing the seminar topics and discussing what they have learned. At the end of the course, student groups are required to demonstrate their design through a final formal presentation to the faculty, fellow students, peers and a jury of industry guests and faculty from other departments (see Fig. 1). Students also write a detailed design report as part of the course requirements.

Motivation for the Project

The proposed project was motivated by the lasting role that multidisciplinary design has claimed in engineering/technology and the realization that 21st century innovations in engineering involve “out of the box” ideas. For the past two years, the author has invited Dr. Greg Hull, Assistant Professor from the Herron School of Art to the senior design class to talk about “The Design Process in Arts and Sculpture”. Dr. Hull reviewed information on the design processes in Arts and Sculpture and also brought out the parallels between the design processes in the Arts and Engineering. It was interesting to note that art and design are very closely linked and art and design have been used in conjunction from the very early days of mankind. One can find many examples of the combination of art and design in architecture such as bridges, buildings, etc. This exposure to various design topics from diverse perspectives has been extremely beneficial in encouraging our ME students to be creative and original in applying their emerging design skills. Based on the interactions with guest speakers and discussions, an interesting capstone design project was carried out in Spring 2003. This project experience is presented in this paper. The research literature on design processes in arts and engineering became a resource for our students as they embarked on a most interesting and productive capstone design project the Purdue School of Engineering and Technology, IUPUI, has seen to date.

Project Scope

An interesting capstone design project was carried out in Spring 2003. The project objective was to design, build, test, and evaluate a creative interface between the visitors and Rhinos at the Indianapolis Zoo that provided the visitors with a knowledgeable and fun experience. The design criteria included safety, durability, and timeliness, in addition to customer requirements. During this semester, two student groups (I and II) were specifically assigned to design this interactive exhibit. The main difference between groups I and II was that

an Art student was deliberately assigned to group II to compare the teamwork and learning experiences of the two groups.

The student groups in the capstone design were assigned by the author based on the interests and talents of the students with a view to maintain a good balance and keeping in mind the type of design project. The other aspects considered in assigning project groups and students include work effectively in teams, communication and presentation skills, build a sense of community, and complexity of the design project. Usually there are 3-4 students in each group in the capstone design course. The author assigned 4 engineering students to Group I, and, one art student and 3 engineering students to Group II to effectively evaluate the final quality of design. The assignment of groups and projects are based on author's experience in teaching design related courses with the overall objective of achieving a good design in the capstone course. The design teams (Groups I and II, and others in the capstone design) were mentored through out the semester by regular weekly meetings/presentations after the design process was reviewed in the first 3-4 weeks of the capstone design course.

Group I developed a vibrating plate illustrating the transfer of vibrations caused by rhino movement, and a device for comparing human weight with rhino weight. Group II created a very different exhibit. A rhino's head was designed to give visitors a feel for how the rhino uses his senses such as vision and hearing. Rhinos have split vision in that they can simultaneously see in two different directions. The students' design allowed humans, who have unidirectional vision, to see in two directions—a disorienting experience that is interactive and can be informational.

Group II also created a “rumbling bridge” by attaching rumbling motors to the underside of a bridge triggered by an optical sensor for detecting rhino movement. The objective of this design was to make the walkway rumble when the rhinos walk by. This station is meant to convey the massiveness of the rhino by rumbling when a rhino walks by. The rumbling bridge is inexpensive to build and when calibrated correctly, conveys the bulkiness of the rhino's steps while keeping the vibrations subtle enough to not jeopardize the safety of the people walking across it. To complete the effect, whenever a rhino shakes a bush while marking territory, a bush in the walkway also shakes with small oscillations to keep the exhibit safe, but still attract attention. The rhino's head design is briefly described below.



Fig. 2. Rhinos Head – (a) Concept

(b) Prototype

Rhinos Head: This station was designed to give people a feel for how the Rhino uses his senses such as vision and hearing. Rhinos have split vision in that they can simultaneously see in two different directions. This station will split human vision, which is unidirectional, and make the viewer see in two directions. This concept is very disorienting for humans and is therefore interactive and informational. The concept and prototype is shown in Fig. 2.

The other two competing designs in the capstone design course included “Radial Artery Device”, and “Automatic Music Page Turner.” Group II won the best design award for Spring 2003 among four other designs judged by a jury of faculty and industry guests on ME Design Day held on May 7, 2003.

The jury used an overall criteria (see Table 1) consisting of project objectives; use of engineering principles; creativity and originality; impact of design on safety, environment; society; ethics and professionalism in presentation and answering questions; and the overall design quality to evaluate the winning design. The design faculty felt that group II demonstrated more creativity in their design as compared to the other design groups.

Project Feedback

The feedback from both the engineering students as well as the art student was very positive in terms of learning habits, group dynamics, and working/learning experiences. The art student liked the design experience, and has signed up for an independent study course this summer. The ME students like the work ethics and attitude of the art student, and felt that there was a great contribution in planning and creating phases of the design.

The capstone project discussed above further strengthened our commitment at the ME Dept to provide opportunities for our students to appreciate creative designs from arts as well as other perspectives and gain a deeper understanding of multidisciplinary design techniques. It is very likely that multidisciplinary design projects such as the one described above, will be increasingly developed and implemented in institutions of higher learning across the country as more art and engineering collaborations lead to creative design projects and valuable learning experiences for students. Such design projects also have the potential to attract women and minority students to pursue science and engineering fields along with liberal arts programs.

Concluding Remarks

This paper discussed the development and results of a unique arts and engineering collaborative capstone design project in the ME Dept at IUPUI. This project was judged very positively by a jury of students, faculty and guests from industry for its technical and artistic merits and relevance for the local community. The author hopes that information on this project will stimulate even more creative multidisciplinary design collaborations across the country and further enhance the learning experiences of all students.

Table 1. Jury evaluation of capstone design course at the end of semester

Design Team: _____

Note: All items are scored from 1 through 5, with: 1 = Poor, 2 = Fair, 3 = Good, 4 = Very good, 5 = Excellent).

1. **Project Objectives:** The description and objectives of the design problem investigated
1 2 3 4 5
2. **Creativity and Originality:** The degree of creativity and originality demonstrated in the design project
1 2 3 4 5
3. **Use of Engineering Principles:** The soundness of the engineering principles used and understood
1 2 3 4 5
4. **Impact of the Design on Safety, Environment, and Society:** The completeness of the design including the consideration on safety, environmental, and societal impacts
1 2 3 4 5
5. **Professionalism and Team Work of the Design Group:** The degree of professionalism, team work and knowledge demonstrated during the presentation
1 2 3 4 5
6. **Effectiveness of the Presentation:** The overall effectiveness of the student group presentation
1 2 3 4 5
7. **Life Long Learning and Ethical Aspects:** Demonstration of the importance of any life long learning and ethical aspects by the team
1 2 3 4 5
8. **Overall Quality:** The quality of the capstone design project demonstrated by the student group
1 2 3 4 5

Date of Evaluation: _____

Evaluator: _____

Signature: _____

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Biographic Information

Ramana Pidaparti received his Ph.D. degree in Aeronautics & Astronautics from Purdue University, West Lafayette in 1989. Since August 1989 he has been with the Department of Mechanical Engineering at Purdue University campus in Indianapolis (IUPUI) where he is currently Professor of Mechanical Engineering and serves as the Director of Academic Programs. Dr. Pidaparti has published over 130 technical papers in refereed journals and conference proceedings in the areas of composites, fracture mechanics, biomechanics and finite element methods. His current research interests are in engineering design, assessment, advanced composites, biomedical engineering, adaptive devices design, and nanotechnology. He is a member of Tau Beta Pi, Sigma Gamma Tau, and Who's Who societies. He is a member of professional societies including AIAA (Associate Fellow), ASME (Fellow), and ASEE.