

AC 2007-1831: THE IMPACT ON STUDENTS OF FRESHMAN DESIGN PROJECTS SUPPORTING ADVANCED COURSES

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The Impact on Students of Freshman Design Projects Supporting Advanced Courses

Abstract

The Accreditation Board for Engineering and Technology (ABET) identifies design as an important element of the engineering curriculum. The faculty at the University of Tennessee at Chattanooga (UTC) believes the concepts and principles of design are as fundamental to undergraduate engineering education as are those tools and topics traditionally thought as fundamental (such as mathematics, physics, chemistry, statics, and dynamics). The faculty also believes, as supported in the literature, that getting engineering students involved in hands-on projects early in their academic career motivates students and aids in retention. This paper describes the process and outcomes of using Project-Based Learning, specifically hands-on design projects supporting upper level course work, in the freshman design course. Student motivation and learning are discussed as well as specific project outcomes.

Introduction

The Engineering program at the University of Tennessee at Chattanooga (UTC) recently redesigned its freshman introduction to engineering design course (IED) to use Project-Based Learning (PBL) to excite students to independently learn, to create an environment for peer learning, and to increase student in-class and out of class participation. It is believed that these objectives are instrumental for exciting students about engineering, for increasing student retention, for motivating learning, and for improving students' knowledge transfer capabilities especially in the application of engineering design.^{2,3,6}

As a part of the PBL emphasis the IED course structure now culminates in customer supported student design projects. Some of the project customers are instructors of sophomore, junior, or senior level courses. To solicit these projects, the IED course instructors distribute a call for project proposals to the faculty and staff of the UTC College of Engineering and Computer Science (CECS). Interested instructors submit the two page proposal which is reviewed for applicability to freshmen design and technical knowledge (many of the students have not yet taken any other engineering course). The instructors know to constrain the projects so they can be completed in seven weeks but to make them complex enough to have a variety of solutions to allow the students to participate in decision making. Students model their final solutions using 3D software and fabricate them in the College's machine shop.

At present one to four projects each semester support either upper level courses or upper level design team projects. To develop the knowledge needed to successfully experience the design process and to develop successful designs for these projects, students are introduced to technical theory and applications associated with the advanced courses (through the sponsoring faculty). The initial review of student reaction to the completion of these projects caused the sponsoring faculty and course instructor to examine the role of these projects in exciting students about engineering and motivating their learning.

design. Major course deliverables include 3D models and a working prototype of a culminating team project.

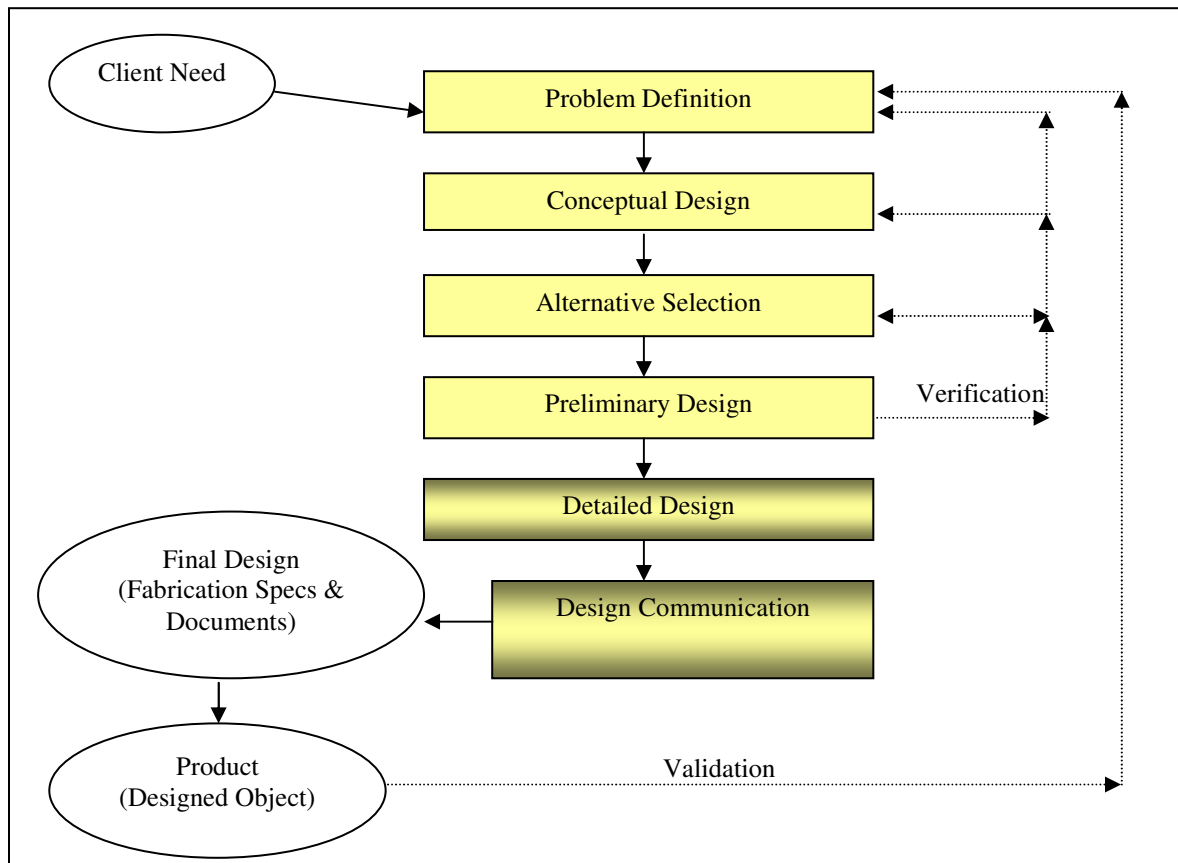


Figure 2.0: The Design Process (UTC Emphasis)

IED Course Structure

IED meets for 4 hours each week as two 2-hour class sessions. The first 2 weeks, using a simple design project, introduces students to solids modeling and the concepts of graphical communication. During the next 4.5 weeks the students are introduced to and practice the components of the design process through a larger class project. The last 7.5 weeks are devoted to the students applying what they learned about the design process and graphical communication to a small team project. The project culminates in a project prototype.

IED Course Learning Objectives

After completing the IED course, the students should know how to

- formulate a problem statement
- create project objectives
- distinguish between functions and specifications
- use idea generation exercises to generate alternative solutions to a problem
- use at least one proven means for deciding between design alternatives

- recognize and communicate constraints and codes and/or standards for a design
- recognize and apply ethical decision-making practices.
- organize, participate in, and document team meetings
- participate as a contributing team member in the design and problem solving processes

They should also be able to

- apply graphical 2-D and 3-D drawing principles
- use a 3-D drawing software package
- use the principles of good oral communications to effectively communicate major ideas
- use Microsoft PowerPoint software to aid oral presentations
- use Microsoft Project for creating a simple Gantt Chart
- use principles of good technical writing to effectively communicate major ideas

The IED Culminating Project

The goal of the IED team project is to design a device for a specific customer. Since the fall of 2005 the projects consist of opportunities from (1) a grant from the Tennessee Department of Education and (2) UTC faculty needing small devices to support research or upper level courses or projects. Early in the semester a request for project proposals is sent to the grant participants and the faculty of the UTC CECS. The course instructors select those proposals that best meet the needs of the course and the abilities of the freshman students (many of these students have yet to take an engineering course). The projects must include a three dimensional application as well as constraints to bound the design.

Approximately nine projects are selected each semester (4 to 5 students per project). One to four of the projects are sponsored by faculty. Faculty sponsors are requested to mentor the project teams as they progress through the design process to help them acquire the technical knowledge necessary to complete the project. The course instructors support the technical needs of the grant sponsored projects. The team project process is outlined in Figure 3.0.

IED Faculty Sponsored Projects

Between the fall of 2005 and the fall of 2006 UTC CECS faculty have sponsored ten IED projects. Two of these projects supported the 2006 Junior/Senior MiniBaja competition vehicle project. Two other projects supported the college's engineering mechanics and the civil engineering structures courses. Other projects supported the college's vector statics course, a research project, and a Tau Beta Pi Chapter project. Following are descriptions of some of the projects.

MiniBaja Projects

During the fall of 2005 the faculty sponsor of the MiniBaja Junior/Senior project requested help from the IED course to help build the MiniBaja. The MiniBaja steel chassis was fabricated in accordance with design plans and specification generated by the UTC MiniBaja Race Team. The chassis tubing was chrome-moly seamless steel alloy (4130) having outside diameters that range

from ¾” to 2”. The principal steps in the welded fabrication process included cutting, bending, end preparation, fit-up, and welding.

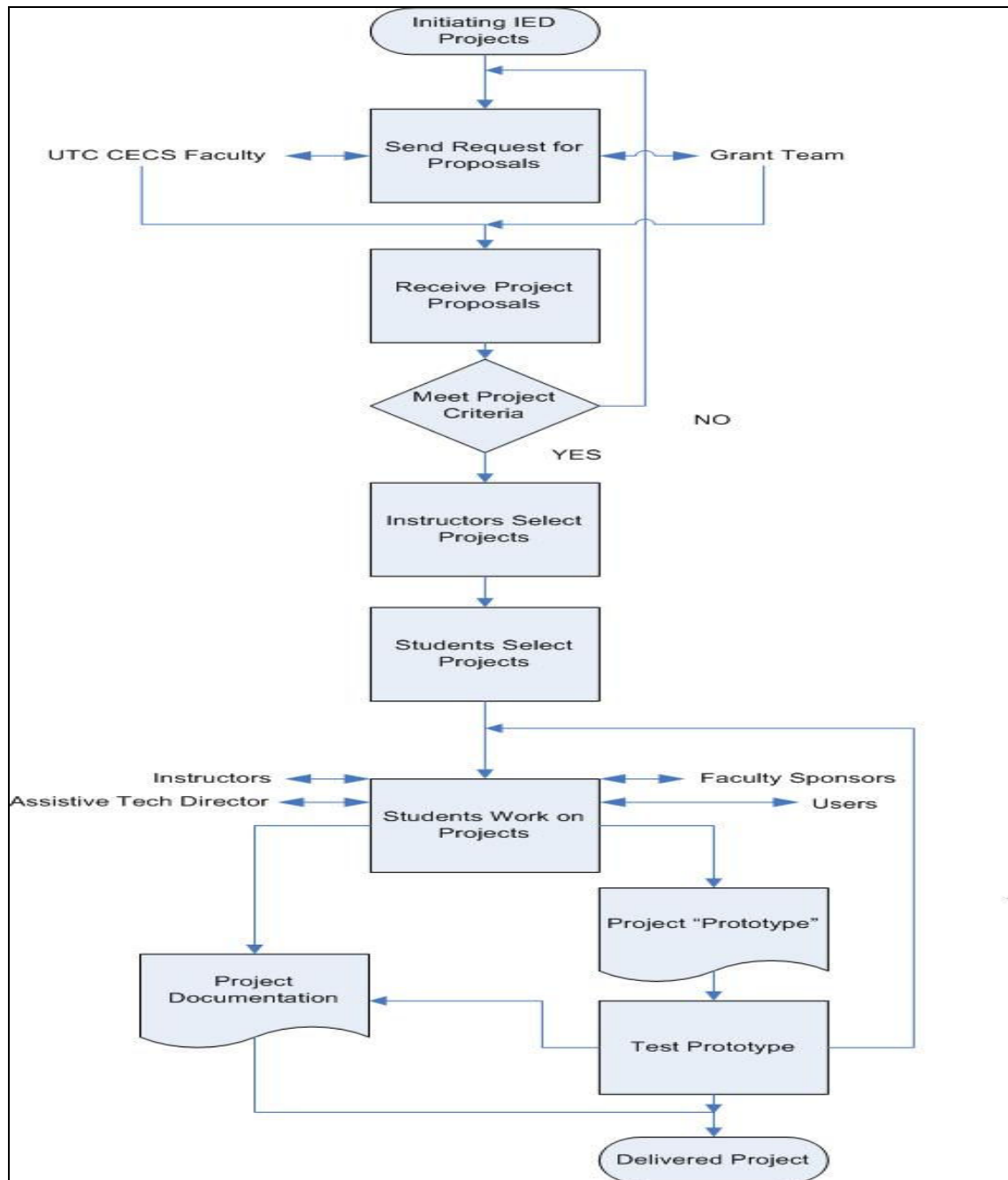


Figure 3.0: IED Team Project Process

The UTC Engineering Shop was not equipped with a *Tubing Jig* to cope tube ends or with a *Welding Jig* to hold and secure tubes for welding. To meet this need, the Baja Student Team sought the IED course for support to design and build functioning jigs. Two IED teams were formed. Each consulted with the Baja team and the faculty advisor to define the problem, functions and constraints. Both teams developed designs and rendered them in Solid Works.

Each team purchased and fabricated the various jig components. The Tubing Jig was completed and delivered at the semester end. The Tubing Jig was hugely successful. It reliably supported tubing stock for cutting at predetermined coping angles. The jig was used to prep all welds in the Baja chassis. It remains in service at this writing. Due to lack of time, the Welding Jig, shown in figures 4.0 and 5.0 was not completed by semester's end or put into service.

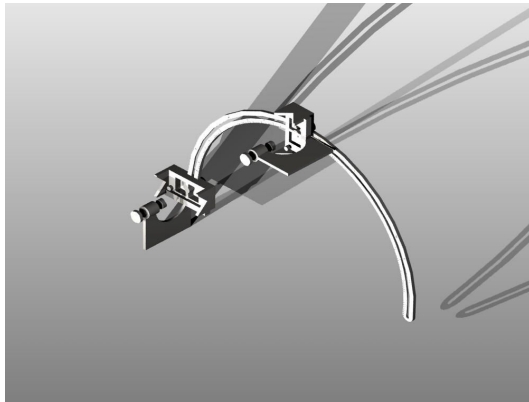


Figure 4.0: IED Designed Welding Jig

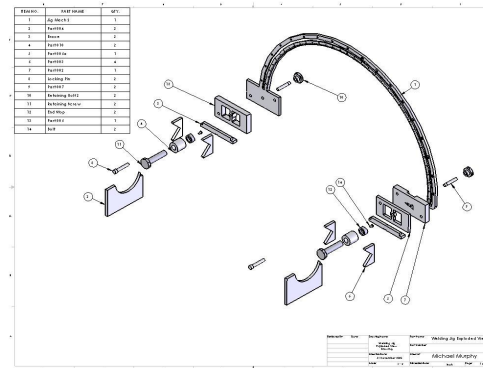


Figure 5.0: IED Designed Welding Jig (Exploded View)

Structures Projects

During the spring 2006 semester one of the civil engineering professors requested that the IED students support a project to develop a shaft/torsion and beam model that he could use to demonstrate twisting and bending of shafts and beams. He was specifically interested in demonstrating the angle of twist in a shaft and the bending deflection in a beam. The search for a material was the most critical aspect of the project with the design of the member size a secondary goal. A major constraint of the design was that the model had to fit on a 12 inch by 12 inch support panel that could be viewed using a document camera. This model was so successful that the professor requested that a Fall 2006 IED team design a second model to demonstrate bending or buckling of multi-span beams and beams with fixed and pinned end conditions.

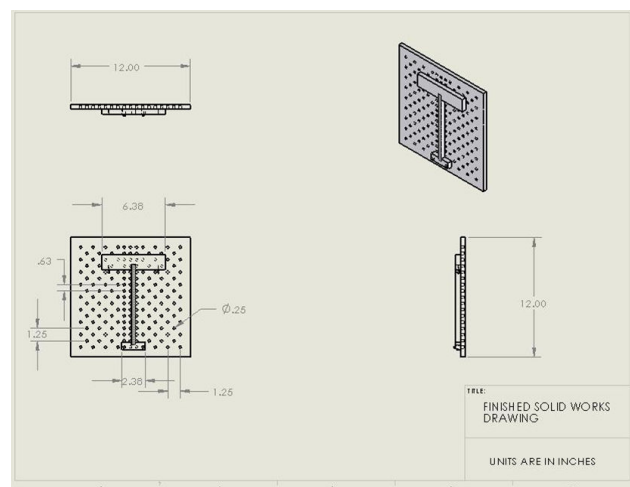


Figure 6.0: Beam Buckling Model

The product of the Fall 2006 IED team is shown in Figure 6.0. The buckling model consists of a 12 inch by 12 inch clear acrylic board, a clear acrylic support, a clear acrylic bar, and a black polyurethane rubber member. The board has holes spaced evenly to allow acrylic pins to be used to mount supports or simulate a pinned support in the center of the polyurethane member. The polyurethane member includes a grid to show how different sections of the member deform during buckling. A string is attached to the acrylic bar so users can hang weights to apply a compression force to the member.

Truss Project

During the fall 2006 semester another of the civil engineering professors requested that the IED students design a model to demonstrate the function and purpose of zero force members in trusses to his vector statics course students. Its goal is to aid students in understanding the purpose and function of zero force members.

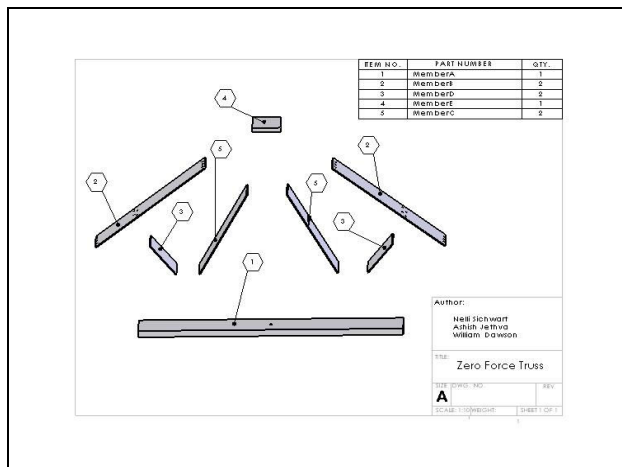


Figure 7.0: Zero Force Truss Model (Exploded)

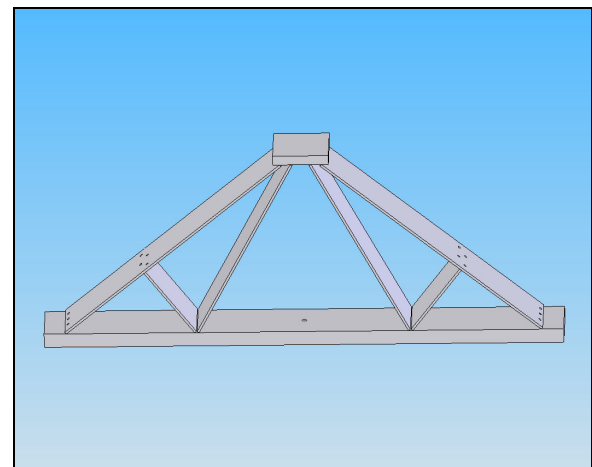


Figure 8.0: Zero Force Truss Model

The completed truss model (shown in Figures 7.0 and 8.0) has a width of 3 in and can stand upright (as shown). All truss members are made of Plexiglas. The base is 26 in long and 0.5 in thick. Two hinges, one at each end, connect the base to the main frame members. Stoppers made of aluminum flashing are located 7.5 in from each end to form the joint mechanism for the inner two members on each side. Holes are drilled through the base directly beneath each joint to hold weights. The main frame members are 15 in long and 0.11 in thick. Aluminum flashing stoppers are placed at a distance of 6 in from the bottom joints. All inner members are made of 0.11 in thick Plexiglas. The longer members are 10 in long and the shorter ones are 4 in long. The top piece is made of Plexiglas 0.5 in thick and is 3 in long. In the middle of the piece is a hook braced by aluminum flashing. The truss is elevated using two wooden pillars attached to a wooden base. It is fixed on one end. Aircraft cables are attached to each joint and fall through the holes in the truss base. Hooks are attached to the cables to hold 1 pound steel disc weights used to generate force on the truss members. By alternating adding weights and removing truss members, students can observe the use of zero force members on truss geometry.

Torque Test Panel

During the fall 2006 semester one of the UTC CECS mechanical engineering professors requested that the IED students support research of his in the orthopedic field. The goal was to develop a panel to test the torque required to insert screws into a bone to fixate fractures. Knowing the torque required to insert these screws is important because if too loose, the resulting fixation fails to immobilize the fracture but if over-tightened the bone will evulse, “or strip”, and render the fixation useless. The goal is to have the screw tightened to the maximum possible torque without stripping. Seasoned orthopedic practitioners believe they possess the “feel” to sufficiently tighten the screws without evulsion. Some believe they are able to consistently apply a desired magnitude of torque, expressed as a “squeak” or in units of “finger tight” such as “two finger tight” or “three finger tight”.

This team researched the needs of the panel and developed a high level prototype for holding the bone for screw insertion (see figure 9.0). The project goal was to prove the concept by bench testing a prototype comprised of IED developed and fabricated components and a stock pile of available test instrumentations (load cells, encoders, DAQ). This goal was not realized. This project will be revised and presented as a project option to the Spring 2007 IED class.

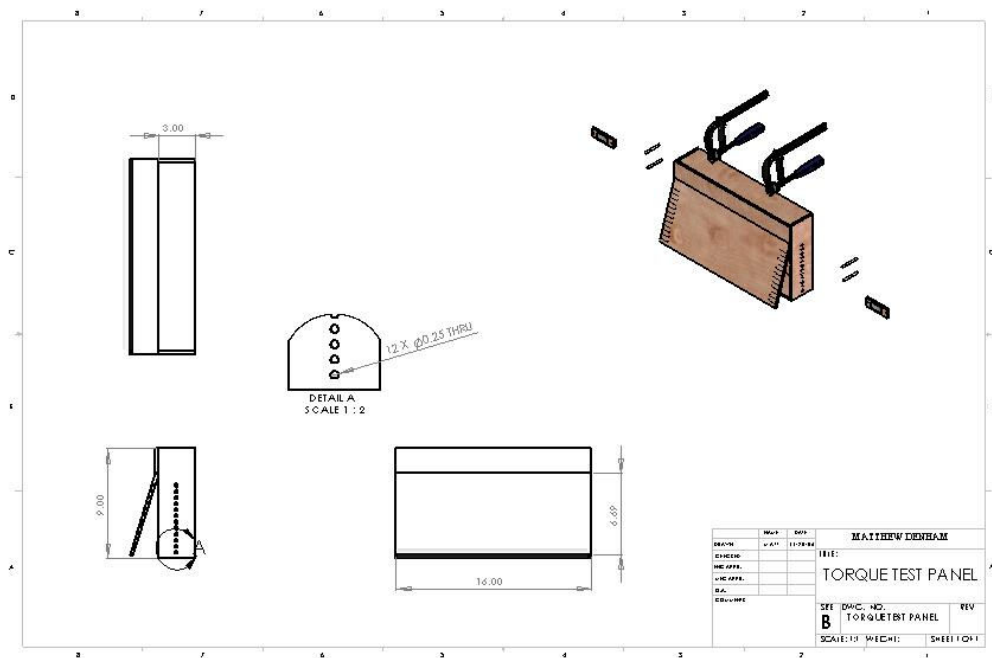


Figure 9.0: Torque Test Panel

Role of the Faculty Project Sponsor

The main role of the faculty project sponsor is to provide the project goal and high-level objectives and constraints. If the project is supported by grant supported research the faculty member is also responsible for the project cost. Otherwise the College provides a \$100 to support each project.

Upon receiving the high-level project needs and requirements, the student team must take the initiative and research the project topic and meet with the faculty sponsor to discuss further the needs of the project. The faculty sponsor is not required to have regular meetings with the student team though one or two sponsors have chosen to do so. The faculty sponsor is requested, however, to provide the students the technical resources necessary to help them produce a successful project. This may require regular meetings for transferring technical knowledge or providing contacts for observing or interviewing possible device users or customers (such as the orthopedic surgeons).

The faculty sponsors were also asked to attend the final student presentation of the project and to evaluate the presentation as well as the final design and product.

Learning Outcomes of the Projects

The faculty sponsored projects have impacted both the students in the IED course and those associated with the upper level courses and projects for which they were designed. The following summarizes these outcomes.

The IED Students

The learning outcomes of the IED course, presented previously, highlight that the IED course's goals are all associated with students being introduced to the concepts of the design process. However, the course instructors are finding that the students who participate in the faculty sponsored projects are learning much more. For example, those students who participated in the column and beams model projects learned the importance of material selection (a sophomore level consideration). Specifically, they were introduced to the role of material properties in meeting material application specifications. Also, these students, similar to those who participated in the Zero Force Members project, learned of concepts associated with theories they would not have been introduced to until they participated in the related course. For example, the columns and beams model team learned that doubling the size of a dimension can reduce the twisting or deflection more than a factor of two – an important concept in reality and in building the model.

Another important concept is the definition of beam failure. One of the design constraints for the Zero Force Members project team was to design a truss whose members could be removed individually from the structure. The object was to show that if a non-zero force member were removed the action will result in total collapse, whereas if a zero force member were removed, the action would result in an intact structure (unless the member served a stability purpose). During the design process the students realized that it would be difficult and more time consuming to demonstrate total collapse of the structure. Through discussions with the project sponsor the team learned that failure of a beam or structure is not only defined by catastrophic failure but also by excessive deflection. Thus, the team determined they could meet the design constraint by showing that removal of a zero-force member resulted in excessive deflection—a key realization for project success.

The concepts the students learned apply not only to technical theories and applications but also to design process application. One such learning opportunity presented itself to the columns and beams project team. Those students who participated in the revision of the columns and beams

model learned of the importance of adapting the accomplishments of previous modeling and testing results. The fall 2006 teams used the material selected and the base designed by the spring 2006 team to build a model to meet their project's criteria. The spring 2007 IED team addressing the orthopedic torque test stand will have a similar experience.

Using real customers has also helped students to learn the importance of working closely with the customer. Previous to the fall of 2005, students developed projects of their own interest. They had no interaction with a customer who could examine their design and provide feedback. They also did not have to meet customer required constraints. Now, with customer supported projects, students learn that feedback and interaction with the customer is extremely important to create a successful outcome. For example, the spring 2006 beam project team had only one meeting with the customer after material selection. The result was that the sizing on the beams was not optimum to demonstrate all functions desired by the project sponsor. This lack of interaction and the resulting consequences were discussed with the following semester's design team which resulted in much improved communication and results.

Other Students

The examples above illustrate that students can be introduced to upper level course concepts through a small introductory hands-on design experience and learn important theories. Also interesting is how the projects can also reinforce the knowledge gained from the course they are supporting. For example, all the participants on the Zero-Force Members team had completed the vector statics course (the course the project supports) prior to beginning the project. Thus, they were familiar with the theory on how to identify zero-force members. However, in a post design interview with the project sponsor, all the students were emphatic in their assessment that the project enhanced their understanding of zero-force members and their role in trusses. This positive feedback is also an indication that the project product will serve a useful purpose as an effective teaching prop in subsequent vector statics classes.

The students in the engineering mechanics and civil engineering structures courses also benefit from the IED models. The instructor can now use the beams and columns models and a document projector to physically show how structures twist, bend, and buckle under varying loads and supporting conditions. Thus the students have the opportunity to develop a visual understanding of how and why structures behave a certain way under certain loads. This visual understanding is critical for structural engineers. It can alert an engineer to the dangerous bending and twisting of a structure that could lead to a complete collapse.

Conclusion and Considerations

In reviewing the discussed projects and those not discussed above, the course instructors and the faculty project sponsors find the IED project program a success. The students are learning about the design process, they are applying the design process, and they are working with real customers with real needs and demands. Most of the students take these projects seriously and produce successful devices. They enjoy the 3D modeling exercise and the hands-on building of the device. Most of the students communicate that they learn more than the use of the design process when they participate in these projects – they learn about courses and topics they will take in the near future. In addition, they find it interesting to see their devices being used by instructors and, as was the case for the MiniBaja project, fellow students.

However, there are still those projects that are not successful. One discussed above, the Torque Test Panel, did not result in the desired outcome. This is due to the students not taking the initiative to contact and meet with the instructor as needed. This project required more initial research than the team was willing to put into the project. They lacked motivation. Sometimes the lack of motivation occurs due to the make-up of the team. The students are allowed to select their own teams. Thus, they may be on a team with many of their close friends. Sometimes the lack of motivation occurs due to a lack of understanding of or a poor communication of the customer needs and criteria. The course instructors have tried to improve the required project proposal content to minimize poor communication. Another possible cause of low motivation is that freshmen naturally shy away from unfamiliar faculty. The IED instructors are presently considering a more structured process to compel students to more closely work with the faculty.

Some projects are also not successful due to the prioritizing of projects in the engineering shop or the need for special material or material processing the shop can not provide. The shop is supported by one full time person and one part-time person and there are many projects being completed at the end of the semester. Thus the project load on the shop is heavy and some projects, especially those of teams with little shop experience or those that require special material or processing, may receive low priority. Students are reminded to get their projects to the shop early to ensure they are completed by the end of the semester. The project instructors are also looking into opportunities to expand the resources of the engineering shop.

Expanding the Program

Five UTC CECS faculty have participated as sponsors of IED team projects. These sponsors have come from the mechanical, civil, and design programs. The course instructors hope to get more faculty involved. However, getting the electrical faculty involved is more difficult since the IED students have limited academic background in circuits and power and thus are not provided projects that require electricity as an input or output. But this constraint should not limit participation. It is believed that, as more faculty participate and more are introduced to the products, additional faculty will desire to be part of the program and will propose creative and applicable projects.

Considering other Outcomes

Being a small program, the faculty supporting the IED projects tend to have IED students in their own courses or supporting a student project (such as the MiniBaja) later in the students' academic careers. These students provide the faculty feedback on the impact of IED. For example, one such student confided to the Tubing Jig faculty sponsor ambivalence about engineering at the onset of his first semester at UTC (when he took IED). However, the IED project and interest in the greater Baja project stimulated in him an interest in engineering. Three semesters later this student is much more confident in his choice of career path and is flourishing academically.

The research on student retention supports this reaction from the student. For example, The University of Colorado at Boulder revealed in the study of their first year engineering project course that the retention rate is significantly higher for those students who participate in the hands-on learning experience.⁴ Baylor University found that a key to freshmen engineering

retention is its introductory freshman course and its pedagogic approach – when they added a design project to the course retention increased.⁷

UTC Engineering has yet to quantitatively determine the relationship of IED to student retention. The present PBL structure is young (2 years) and thus little retention data is available. We are presently collecting, using a student survey, data on how well the course meets its objectives. However, we need to improve the survey to collect data on the projects' impact on students' desires to continue in engineering. The improved survey will be administered the end of the spring 2007 semester.

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