The Role of College Sponsored Freshman Projects Engaging Freshmen - Engaging Faculty

Cecelia M. Wigal, Ph.D. P.E.[1]

Abstract – The Accreditation Board for Engineering and Technology (ABET) identifies design as an important element of the engineering curriculum. The engineering 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. However, what other benefits are there of freshmen projects, especially those projects sponsored by College faculty? This paper describes the process of using hands-on design projects supporting the needs of College instructors, professors, and upper level projects, in a freshman design course. The role these projects play above improving student retention is identified.

Keywords: Freshman projects, project-based learning, undergraduate research

INTRODUCTION

In many engineering programs, especially those that are large, freshmen engineering students have limited contact with engineering faculty. In smaller programs, freshmen students may have contact with a few engineering faculty through introductory engineering courses; though most contact is with faculty in the math and supporting sciences disciplines. The result is that freshmen students are not engaged with the engineering program and the engineering faculty are not engaged with the freshmen students.

How can this engagement be improved? Studies indicate that Project-Based Learning (PBL) is one means to increase student engagement. [2] [3] [6] Further research indicates that this engagement results in increased student retention. [4] This paper, through the discussion of a course structure and course project outcomes, suggests that, though it is proven hands-on learning improves student retention, there are other equally important outcomes.

The course introduced here is the program required Introduction to Engineering Design (IED) course. In this course engineering students work on projects supported by faculty of sophomore, junior, or senior level courses, faculty with supported research, or faculty advising student engineering society projects or upper level design projects. The instructors find that these projects provide faculty-student mentoring opportunities, build student-faculty relationships, and empower student engagement.

BACKGROUND

The College of Engineering and Computer Science (CECS) at the University of Tennessee at Chattanooga (UTC) uses Project-Based Learning (PBL) in its Introduction of Engineering Design (IED) course 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

[1] The University of Tennessee at Chattanooga, 615 McCallie Avenue, Dept. 2502, Chattanooga, TN 37403, Cecelia-wigal@utc.edu

especially in the application of engineering design. [2] [3] [6] These are many of the reasons this course was developed eight years ago.

As a part of the PBL emphasis the IED course structure culminates in customer supported student design projects. Some of the project customers are instructors of sophomore, junior, or senior level courses or professors leading research, or staff supporting student clubs and/or competitions. 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 these college faculty and staff 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 or research (through the sponsoring faculty). It is the initial review of student reactions to these projects that caused the sponsoring faculty and course instructor to reexamine the role projects play in the students' education.

IED Course Structure

IED meets 4 hours each week as two 2-hour class sessions. In the first 2 weeks, using a simple design project, students are introduced 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 that is delivered to the customer.

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 and staff 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 and staff 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.

Eight to twelve projects are selected each semester (4 to 5 students per project). One to four of the projects are sponsored by CECS faculty or staff sponsors. The sponsers 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 projects. The course instructors support the technical needs of the grant sponsored projects. The team project process is outlined in Figure 1.0.

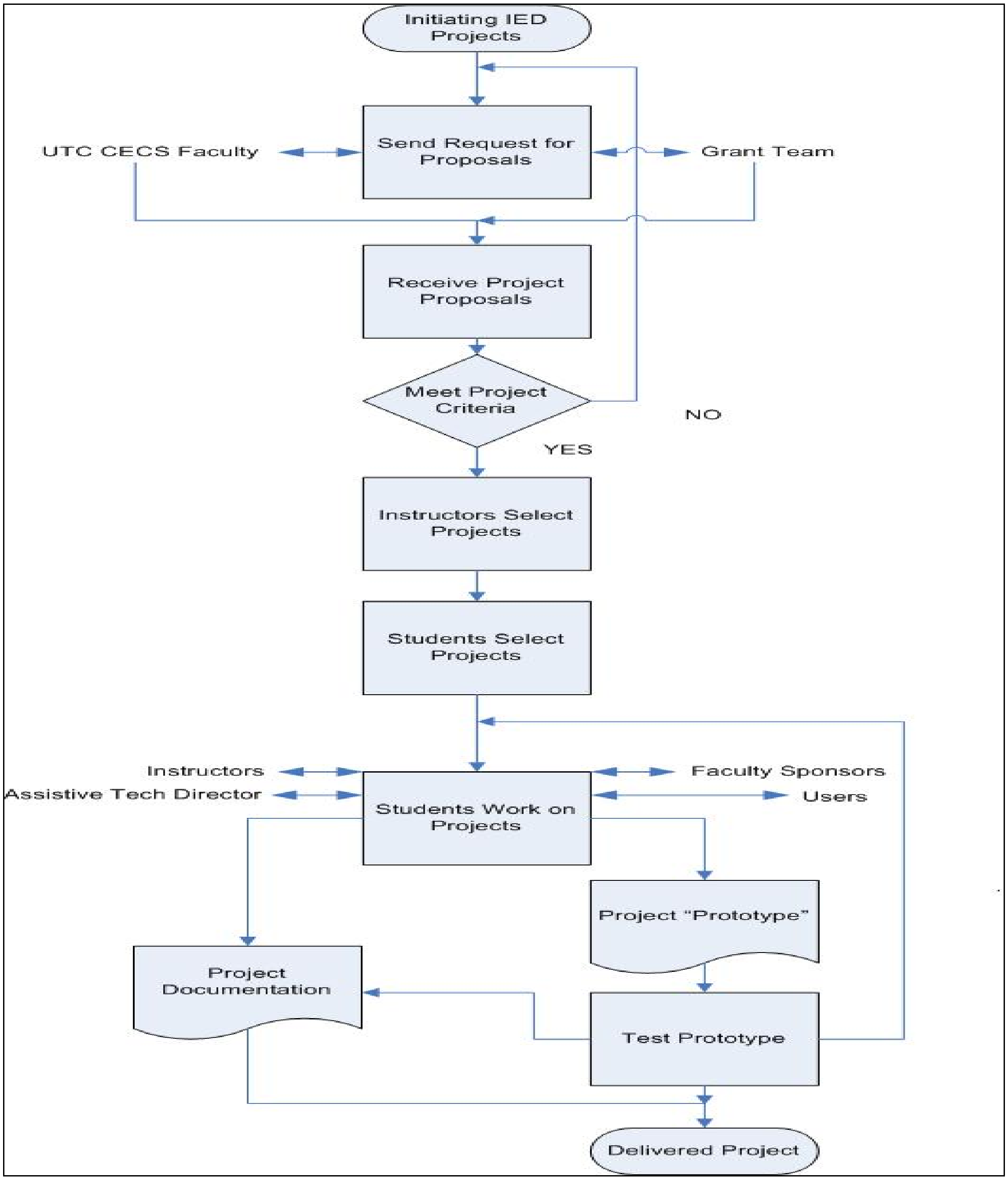

Figure 1.0: IED Team Project Process

ROLE OF CECS PROJECT SPONSOR

The main role of the CECS 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.

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 CECS sponsor to discuss further the needs of the project. The CECS sponsor is not required to have regular meetings with the student team though one or two sponsors have chosen to do so. The CECS 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 CECS 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.

IED CECS SPONSORED PROJECTS

Between the fall of 2005 and the fall of 2009 UTC CECS faculty and staff have sponsored over 15 IED projects. Three 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, research projects, and faculty personal needs. 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 specifications 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.

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 very successful. It reliably supported tubing stock for cutting at predetermined coping angles. The jig was used to prep all welds in the Baja chassis. Due to lack of time, the Welding Jig, shown in figures 2.0 and 3.0 was not completed by semester's end.

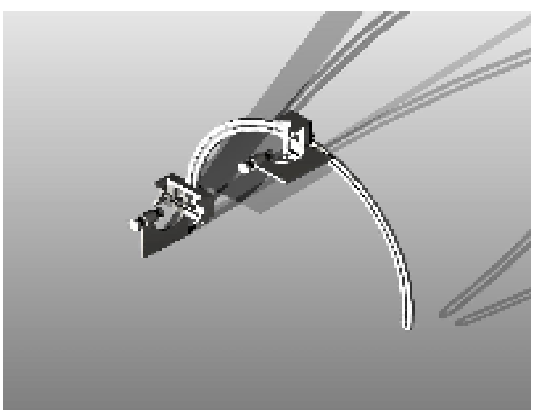

Figure 2.0: IED Designed Welding Jig

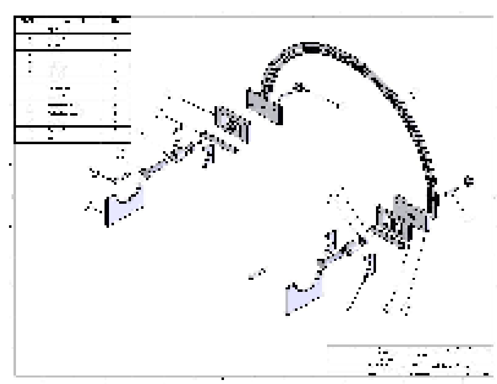

Figure 3.0: IED Designed Welding Jig (Exploded View)

During the fall of 2009 the IED students were again requested to support the Mini Baja project team. UTC's Mini Baja Team (MBTeam) requested that a freshman IED team design a wheeled system capable of carrying and securing a wide range of tools, parts, and equipment to help the MBTeam transport them to and from the various MiniBaja competition staging locations. The IED team adapted a garden cart to meet the needs of the MBTeam by designing (1) a tool separator, (2) a work space and seat, and (3) a reinforced structure. The cart is illustrated in Figure 4.0. The cart will be initially used during the spring 2010 competition. Members of the IED team were invited to participate on the MBTeam and attend the competition.

Figure 4.0: MiniBaja Radio Flyer

Faculty Course Projects

Beam Twisting-Bending-Buckling

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 for the model to fit on a 12 inch by 12 inch support panel that could be viewed using a document camera. This model was so successful 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.

The product of the Fall 2006 IED team is shown in Figure 5.0. 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 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.

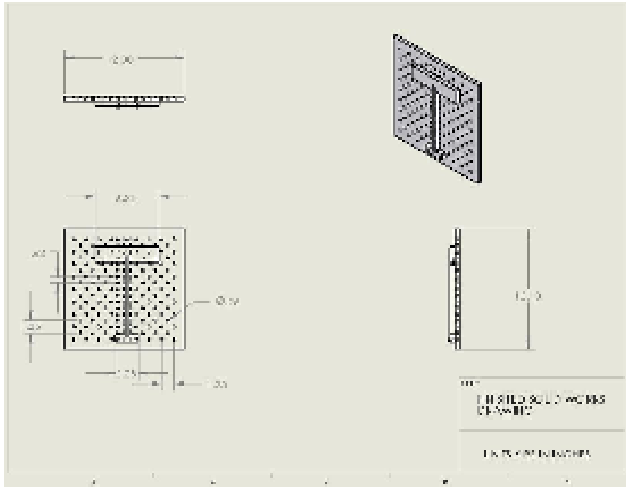

Figure 5.0: Beam Buckling Model

Zero Force Members

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.

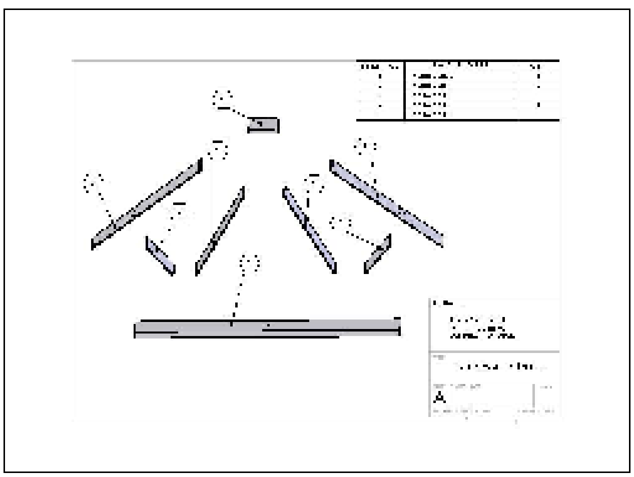

Figure 6.0: Zero Force Truss Model (Exploded)

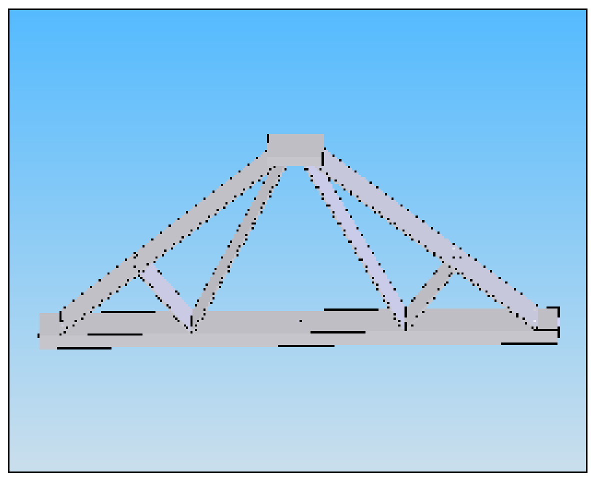

Figure 7.0: Zero Force Truss Model

The completed truss model (shown in Figures 6.0 and 7.0) 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 0.11in thick. Aluminum flashing stoppers are placed at a distance of 6 in from the bottom joints. All inner members are made of 0.11in 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. 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.

Faculty Research Projects

Orthopedic Torque Test Box

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 8.0).

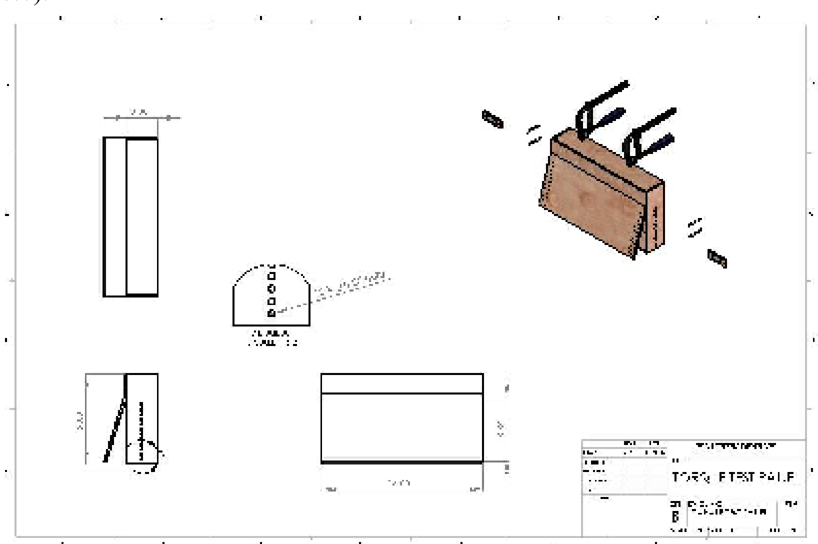

Figure 8.0: Torque Test Panel

Inductive Power Transfer

During the fall 2009 semester another professor asked that an IED student team support research on inductive power transfer (IPT) for recharging the batteries on all electric powered buses. The IPT equipment includes a pick up coil (F-Pickup) which must be mounted on the bottom of a bus (see Figure 9.0). This coil must be positioned within one inch of the primary coil which is stationary, either buried flush with the pavement or on a raised island that the bus straddles for recharging. The problem needing investigating was how to place the pick up coil into the required position above the primary coil for effective power transfer.

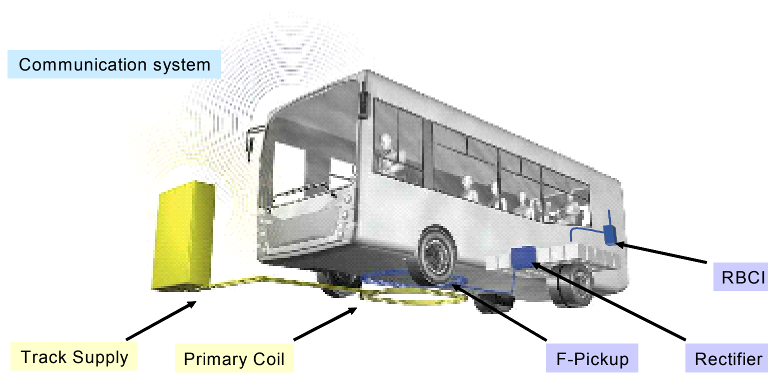

Figure 9.0: IPT and Electric Bus

The project team researched this topic by reading material provided by the project sponsors that include a student team report from a Senior Design Team that work a related issue the year prior. The final product of their project is a virtual rendition of an IPT alignment system (see Figure 10.0).

This system consists of a side-to-side (x-axis) alignment system, a vertical (z-axis) alignment system, and a forward-backward (y-axis) position-indication system. The main parts of the x-alignment system consist of an upper mounting plate, a lower mounting plate, and a linear actuator. The upper plate is welded to the bus and holds the rods in place. The lower plate is moved through a 265 millimeter range along the rods using the linear actuator. The main parts of the z-alignment system consist of an upper frame, a lower frame, a "scissor" system, a piston rod, and a linear actuator. The z-alignment system can drop the secondary coil more than 450 millimeters.

The y-position-indication system uses a traffic light to indicate the position of the bus to the driver using a rangefinder. The green light stays lit until the driver is within 152.4 millimeters of the stopping point. When the rangefinder detects that the bus is within 152.4 millimeters, the light becomes yellow. Finally, the light becomes red when the bus is in the proper position.

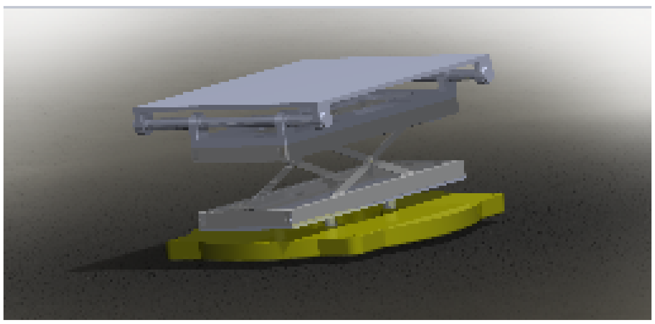

Figure 10.0: IPT Alignment System

Faculty Personal or College Structural Needs

Walnut Collector

Also during the fall 2009 semester, a faculty member requested that students help him design a solution that will make it easy to pick up the walnuts in his yard. His only request was that it use his present riding mower. The student team developed a welded steel structure that includes a hopper, a walnut ramp, and a row of "teeth" to catch the walnuts (see Figure 12.0). The rotation of the row of teeth is driven from a chain and gear mechanism that uses the wheels as the source of rotation.

Figure 12.0: Walnut Picker-Upper

Air Conditioner Protection

During the fall 2009 semester, a faculty member requested that an IED team design a means to protect the air conditioning unit for his lab from traffic in the lab patio. This unit was originally protected by a chain link fence, but due to traffic hitting it, it became an eye sore and was removed. The students researched means of protecting various difficult to see structures and recommended a system of concrete poles. These concrete poles measure 4 feet tall with a diameter of 8 inches. The poles will be set 1 foot into the ground for support. Seven 80 pound bags of concrete are needed to fill the posts. In addition, a fiberglass flag pole and fluorescent flag will be placed at the front most concrete pole to give further indication of the A/C unit's presence. The fiberglass rod will measure approximately 2 feet in length and 2 inches in diameter.

Since this project requires University approval as well as University installation, the design team modeled the system using solids modeling software and built a small scale model. Their design is shown in Figure 11.

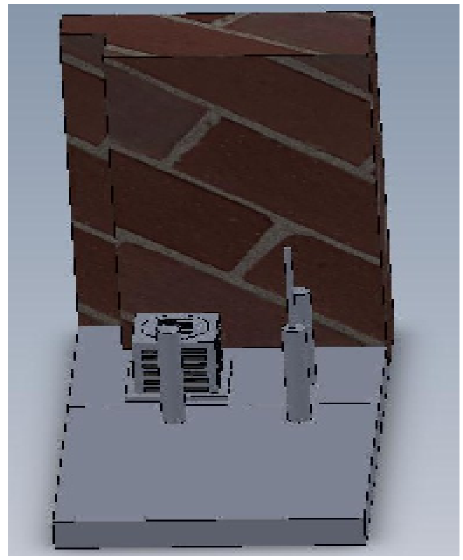

Figure 11.0: Traffic Stopper Design

THE OUTCOMES

It is recognized by the CECS faculty as well as outside observers, that the individual projects, including the projects sponsored by CECS faculty and staff, have been successful as a means to introduce students to the design process. It is also recognized that hands-on projects, such as the projects discussed here, have a role in improving student retention. 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]

But what are the outcomes of projects that specifically involve sponsors from the College? Is improved retention the only outcome? The CECS has found there are other outcomes. For instance, these projects put faculty, who generally do not teach freshmen students, in a position to mentor them. In return, the students get to initiate a relationship with a faculty member they would not necessarily meet until their Junior or Senior years. This has the following results. First, the faculty member recognizes that freshmen students can contribute positively to research and other problem solving initiatives. Second, the faculty members get introduced early on to students who could become a part of their research team. Third, students are introduced to theory and applications in an applied environment they may not otherwise experience until in their upper level curriculum. In essence they get an opportunity to see what is in their future.

The Future

UTC CECS has experimented with the foundations of an undergraduate research (UR) program. This program included freshmen up to senior level students. A number of the students were recommended for the program due to their successful participation in an IED project. UTC CECS desires to formally create an UR program in the near future. (Since UTC CECS strongly emphasizes the undergraduate experience and education an UR program makes much more sense than a graduate research program.)

It is envisioned that the IED course will be a feeder for an UR program and that the UR program will be a feeder for IED projects. Thus faculty will have a supply of students to support their research and the IED projects will have a source of funding. But more importantly, students will have a continued means to interact with faculty, be mentored by faculty, build relationships with faculty, and learn and apply theory that many times is outside the tradition classroom curriculum.

REFERENCES

[1] ABET, *Criteria for Accrediting Engineering Programs*, Baltimore, MD, Engineering Accreditation Commission, Nov. 11, 2003, http://wwww.abet.org/criteria_eac.html, accessed December 5, 2006.

[2] Dym, Clive L., et al. "Engineering Design Thinking, Teaching, and Learning" *Journal of Engineering Education,* January 2005, Vol. 94, No. 1, pp. 103-120.

[3] Flores, Benjamin and Connie Kubo Della Piana, "Undergraduate Student Retention Strategies for Urban Engineering Colleges," 30th ASEE/IEEE Frontiers in Education Conference, October 18-21. Session F1F.

[4] "GEEN 1400 – First Year Engineering Projects: Integrated Teaching and Learning Program, University of Colorado at Boulder, July 2006, http://www.itll.colorado.edu.GEEN1400/indes.cfm?fuseaction+RetentionStudy, accessed February 27, 2007.

[5] Hsi, Sherry, Marcia C. Linn, and John E. Bell. "The Role of Spatial Reasoning in Engineering and the Design of Spatial Instruction" *Journal of Engineering Education*. April 1997, pp. 151 – 158.

[6] Piket-May, Melinda and James Avery. "Work In Progress: Teaching the Art of Learning in Engineering Education" *Proceedings of the 34th ASEE/IEEE Frontiers in Education Conferenc*e. October 20 – 23, 2004. Session F2E.

[7] Treuren, Ken Van, Steve Eisenbarth, and Cindy Fry, "Developing Engineering Student Success – A Retention Study at Baylor University," *Proceedings of the 2002 ASEE Gulf-Southwestern Annual Conference,* March 20-22, 2002. Session IA6.

Cecelia M. Wigal

Cecelia M. Wigal received her Ph.D. in 1998 from Northwestern University and is presently a professor of engineering at the University of Tennessee at Chattanooga (UTC). Her primary areas of interest and expertise include complex process and system analysis, quality process analysis with respect to nontraditional applications such as patient safety, and information system analysis with respect to usability and effectiveness. Dr. Wigal is also interested in engineering education reform to address present and future student and national and international needs.