Capstone Design Projects: More than a Matter of Meeting a Program Requirement

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Abstract

Almost all seniors graduating from 4-year Engineering Technology programs must complete some type of capstone design project. It is of utmost importance that the project selected is not just any project, but rather one that simultaneously enhances the learning experience of students, prepares graduating seniors for the real world, increases freshmen retention, and strengthens relationships between universities and industries. The key to making the most out of capstone design projects is to carefully select ones that will accomplish all of the above. Middle Tennessee State University has accomplished this over the past two years through participation in national competitions such as the solarbike race and the moonbuggy race. In the future it plans to continue this type of collaborative project with the Formula SAE Collegiate Competition. The reason for selecting such capstone design projects is not merely to win an award, but to reap the other more long-term benefits as well.

The participating seniors are involved in all aspects of the process. It is a multi-dimensional task that allows the students to complete the cost analysis, design the product, fabricate almost everything from within the laboratory, and communicate with industry for advice. If a specific part cannot be created within the laboratory, the student may contract a particular industry to do it at their facility. Industries particularly love this type of exposure, especially in a national competition. Finally, each participating senior is paired with a freshman student. It is through this mentoring experience that the freshmen students are enthused and are able to get a glimpse of what lies ahead in the future. As a result, they are more likely to continue persevering in the program and retention is increased.

The many demands of this project prepare students for the real world and reward them with a final project they can take pride in. As one can see, it is a winning experience for everyone involved including the graduating seniors, the freshman students, industries, and universities. Capstone design projects should be more than a matter of meeting a program requirement. Instead they should be a matter of building life experiences and partnerships that will endure and enhance the quality of engineering education.

Introduction

After completing a four-year Engineering Technology program, most students are proficient in the principles they studied in the classroom. Whether recent graduates are able to apply those principles to various situations upon entering the “real-world” is another story. This realization is what eventually inspired one professor at Middle Tennessee State University to investigate creative solutions to such a common dilemma. What eventually transpired was a senior capstone design project that would ultimately serve the following purposes:

- To prepare graduating seniors for the real world
- To increase freshmen retention

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To strengthen relationships between universities and industries

The key to making the most of a capstone design project is to carefully select one that fulfills all of the purposes listed above. Middle Tennessee State University has accomplished this through participation in such national competitions as the Solarbike Race and The Great Moonbuggy Race. When most people think of such competitions, they probably assume that the main objective is to win awards and recognitions. Nevertheless, it is only by looking beyond these temporary things and discovering the more long-term rewards that one can see the true value of such competitions.

As mentioned before, the project was initially established with the intention of introducing soon to be graduating seniors to real world applications. It is important to note that the project is under complete control of the student from the moment the first design is drafted up until the finish line is crossed on competition day. During this long process, the professor overseeing the projects soon began to take notice of the developing relationships between the students at MTSU and industries. For example, if students needed advice regarding their projects, or if perhaps they were not able to manufacture a specific part in the campus laboratory, they would call upon industrial leaders for assistance. It has been MTSU’s experience that industries tend to be very receptive to this type of collaboration with students for several different reasons. First, they make good contacts with potential employees that they get to know through the process of the project. Second, they enjoy the national exposure and credit they receive in the competitions [Foroudastan, 2].

This type of project obviously places many demands upon the participating senior that range from designing and fabricating the product to staying in contact with industry for necessary advice and parts. As a result, the professor observed that with so many responsibilities, the seniors could use some type of assistance. This sparked the idea to assign freshmen students to the projects with the seniors acting as guiding mentors. It was not long before the benefits of this decision became apparent including increased enthusiasm and retention among freshmen.

Thus, a unique collaboration emerged. It is one that simultaneously serves three important purposes that in the end creates a win-win situation for everyone involved. As one can see, this senior capstone design project accomplishes much more than simply meeting a program requirement.

Establishing Project Criteria

In selecting a suitable project, all areas of engineering technology should be considered including statics, dynamics, electricity, strength of materials, energy, computer aided drafting, and project development. The complexity of a single project should encourage teamwork that satisfies and supports the varied interests of the students. The selected project should offer collaboration opportunities – both academically through problem solving amongst team members and with industry through requesting assistance and advice on various aspects of the project [Hirsch, 5]. The project should allow graduating seniors to apply the knowledge they have acquired over the last several years, and apply it through an in depth hands-on approach that most students have never had the chance to experience. In addition to this, the project ought to be up-to-date and contemporary as well as introduce them to professional areas of interest. By integrating a hands-on, problem solving project into the normal method of teaching, experience, and learning centered on students is promoted.

A possible dilemma that one might be concerned about is the extensive demands this type of project puts on a graduating senior. After all, the responsibilities are numerous as the students are required to complete the project from start to finish including the cost analysis, design, and fabrication of the project. The students must also find the time to conduct research and consult various industries when they come across situations for which they may need assistance. A solution to this problem is assigning a freshman student to assist each senior. This is a unique collaboration through which the seniors benefit from the extra help and the freshman gain from being mentored through the close peer relationship that is established. While teaching basic introductory courses that supply the math and thinking skills required, introductory hands-on projects boost the learning curve for freshmen students. In addition it encourages their interest in the field and increases their enthusiasm. This is especially true once race day arrives and they are able to see their final project in action [Foroudastan, 3].
This leaves just one final question when it comes to establishing project criteria. That is, “How does the educator meet the needs of all student backgrounds?” By developing creative options within the curriculum that encourage, challenge, and stimulate interest with a combination of instruction and application. A means to accomplish this goal is using a class project that coordinates the technologies being introduced in class and demonstrates a real-life use of the information. As an added value, an application or use for the final product of the project is important and should be considered in the selection. For instance, the projects selected at Middle Tennessee State University (MTSU) for each class can be concluded through participation in a national race.

A project that allows students to complete it from start to finish enables them to see the big picture. It helps them to deal with issues that they will inevitably be forced to face once they enter the “real-world.” The experience of creating a product from start to finish simultaneously provides a shocking yet rewarding experience that will ultimately give recent graduates an edge in the profession. Moreover, this type of class project will stimulate interest in freshmen students and will improve retention [Akins, 1].

With the above objectives in mind, the selection of Middle Tennessee State University’s first project took place: a solar bike.

**Realization of Project / Competition #1: Solarbike Rayce**

The solar bike provides seniors a problem solving approach to learning that implies involvement in discovering solutions relevant to the needs of the learners. It teaches them to think, to reason their way through practical problems, and to develop a life skill that will help them throughout their careers. As a senior capstone project for the engineering technology programs at Middle Tennessee State University, the solar bike is an excellent choice. The solar powered vehicle allows seniors to apply the knowledge from their previous engineering technology courses, such as statics, dynamics, strength of materials, CAD, electronic circuits, and energy to an actual project that will be realized and used to compete in a national competition. Using course knowledge to develop the solar project inspires seniors by giving them a firm idea of what their specific interests really are and likewise creates a level of interest that encourages enrollment and retention in freshmen students.

Our solar bike is a sophisticated three-wheel design, without pedals, powered by solar panels and lead acid batteries. With a steel, space frame chassis, major project components include wheels and tires, steering, brakes, drive shaft, solar arrays, motor, motor controller, bodywork, and safety devices. All are directly related to the courses supporting the technologies. As both seniors and freshmen get involved with the project, they realize the practical use of what they have learned and are learning.

Overall, technical elements involved in the design and construction processes stimulate interest and provide an avenue for physical and mental involvement throughout the course. Project structure, management, electrical and mechanical engineering principles, communication, teamwork and even budgets contribute to a project package [Vavreck, 6]. Design of the frame involves drafting principles and strength of materials, for example, determining the size of the tube frame required, type of materials used, placement of major components, and the metal elements of the trusses. Statics is relative to the design, for instance, involving load analysis and cantilevered wheels. Students apply static knowledge when doing truss analysis and force calculations.

Dynamics is used to determine torque ratios, gearing ratios, and to calculate power based on wheel diameter. Thermodynamics involves the efficiency of the motor and decisions on maintaining efficiency. Working with the solar cells and batteries introduces energy calculations relative to rolling resistance and aerodynamics of drag. A model of the solar bike was created on a scale of 1:12 and was tested in a wind tunnel to measure aerodynamics.

The electrical systems concern solar technologies, alternative energy applications, use of e-meters, digital circuits, and, for additional challenge, a microprocessor is available and can be utilized, depending on the scope of the assignments. The mechanical considerations include steering, brakes, drive, hydraulics, and more. Parts have been machined under supervision. The project increases knowledge of control and power systems, instrumentation systems, and modern modeling and testing protocols. Even though the freshmen have not taken the courses, they are introduced to the concepts and observe the practical applications under the guidance of the senior mentors. As
one can see, the project accomplishes a dual purpose in that it encourages interest early in the curriculum through the technology-oriented participation and prepares students for entry-level positions upon graduation.

Some of the key components learned through the solar bike project include understanding project goals, defining objectives, creating and implementing a plan, assessing as systems are tested, and project understanding. The project design, construction, and development comprise many avenues for interest stimulation. Starting with a plan, given a budget, students compare prices and quality and develop reasoning for selecting one part over another, making decisions based on judgments concerning the project as a whole. Measurement and verification opportunities are presented, testing and research, additional instrumentation, offer many venues that students are able to explore through such a project.

Some groups of students worked with the motor, motor controller, brakes, steering and other components associated with mechanicals. Another group worked with batteries, solar panels, wiring, and electrical considerations. Others students worked on issues of optimizing the subsystems of the vehicle, minimizing weight and achieving maximum efficiency. The students applied fundamentals from the course, researched their ideas, and developed the capability to design, analyze, develop models, and construct their project. They learned to work independently and work effectively as teams. They learned the value of working together with a sense of responsibility to each other using a hands-on project [Foroudastan, 3].

The bonus to the project was the opportunity to participate in a national race to prove the capabilities of all decisions made regarding their design and construction choices. Thus another element to the project was introduced – the operation of a race-worthy vehicle using solar technology. The faculty provides information and direction as a coach or mentor on the project, rather than an instructor, thus, fostering a positive learning experience with a project that both prepares seniors for the competitive workforce they are about to enter and encourages, stimulates, and motivates freshmen students [Foroudastan, 4].

**Realization of Project / Competition #2: The Great Moonbuggy Race**

The extraordinary enthusiasm of the solar bike team was contagious. It spread throughout the Engineering Technology and Industrial Studies Department at Middle Tennessee State University and soon, ideas for a second capstone design project were being pondered. After some research, faculty and students alike both felt that a moonbuggy project with the ultimate goal of participating in The Great Moonbuggy Race seemed to be an excellent challenge. This competition is sponsored by NASA and gives students the opportunity to simulate what the original NASA moonbuggy team accomplished in the 1960’s. It is a unique project in that the final design is judged not only on aesthetic quality and speed, but also its capability to withstand travel over various terrains ranging from sand to rock. The students and faculty knew it would be extremely challenging, but all were willing to take on the difficult task.

Because of the previous success of the solar bike, it seemed that everyone wanted in on the project. As a result of the overwhelming response of interested students, they were divided into groups consisting of four students each. The first step was that all groups had to come up with their own designs. When this task was complete, all the groups combined to present their ideas and a final design was selected. In the end, the team members agreed upon the 2-can design, which would be modified to accommodate the input of the team members. All seemed good and well. However, upon construction of the 2-can design, the students stumbled across several issues concerning compliance with several competition specifications. As a result, the students had to regroup and decide on an alternate design. They eventually selected a modification of the popular three-wheel design with the passenger to the side of the driver instead of in back. This adjustment was made due to the turning radius. Despite their careful modifications, the students soon discovered through this project that although a design may look good on paper, there might be unforeseen problems once the project is under construction. Nevertheless, the students found their way to the finish line.

The final moonbuggy was made of cold, rolled steel construction using predominantly 1.5” and 1” tubing. The sprockets and most of the front steering assembly were made out of tool steel. The concept for the wheels, hubs and most of the front end was primarily derived from mountain bike technology research. High-pressure psi tires that
were able to carry the side load generated by the three-wheel design were used. In addition, very robust down hill rims that were laced to the hubs in a four cross pattern to increase the side load capacity were selected. Shimano Nexus 7 hubs were chosen for their internal gearing. Not only that, but they are soft and durable and greatly simplified the synchronizing of the shifting since the students used one shifter and two separate hubs to conserve on weight and for simplified control.

The majority of the work was actually completed by the students within the departmental laboratory. MTSU’s resident machinist assisted in the machining of the sprockets. The team was required to complete all aspects of budgeting, researching, pricing of parts, and purchasing. It was through these activities that the students were able to experience the whole picture of engineering technology including the business side. After the completion of the project, one student said, “Sometimes even the best ideas are virtually impossible to accomplish due to manufacturing capabilities and budgeting. We now view our designs not only in terms of a final project, but also in terms of how that design will be executed and built.” Indeed the students learned some lessons, but it was better they learn them while still over the safety net of academia. Now graduating seniors will be able to recall upon this experience when they begin their adventures in the real world, and freshmen students will look forward to making their capstone design projects the greatest yet.

Aside from what is learned in terms of technology, there is another element in this competition that makes it especially unique. Many of the technical elements introduced in this project are similar to that of the solar bike, however, in addition to the design and construction planning, there are written and oral sections of the final competition requiring the team to explain and defend their choices. Those exercises serve as a useful tool in communication skills for freshmen who will have to present in their upper division courses and especially for seniors who will inevitably have to present their ideas throughout their careers.

Even with all of the challenges they had to overcome, the students were still tremendously successful placing in several categories and placing fourth nationwide while competing against some of the top-notch schools in the nation. The students were sad to see race day come and go so quickly. Consequently, both faculty and students have decided to participate in yet another project that will be entered into a national competition in 2004. The project will be the Formula SAE Collegiate Competition.

**Future Projects/ Competitions**

The Formula SAE Collegiate Competition is even more challenging than any project ever attempted by Middle Tennessee State University’s Engineering Technology and Industrial Studies Department. It simulates a “real world” situation in which the team of students is to pretend that a manufacturing firm has hired them to make a prototype car for consideration to be sold to the amateur weekend autocross racer. MTSU will be competing with some of the top-notch engineering and engineering technology universities across the nation. As with the moonbuggy and solarbike projects, the students will be required to complete the cost-analysis, budget, design, and fabrication of the project from start to finish. MTSU’s faculty and students are prepared to take on this highly competitive project next year with more dedication than ever before.

**Conclusion**

As demonstrated at Middle Tennessee State University, capstone design projects, if carefully selected can serve a multitude of purposes. Seniors partake in a type of project from which they not only receive credit, but also a wealth of knowledge that without a doubt will help them throughout their careers. The benefits for freshmen students include introducing the students to a wide range of engineering and engineering technology disciplines, promoting inquiry by stimulating interest, encouraging self-assessment while working with peers, and encouraging and stimulating learners with a hands-on, problem solving, ‘let me see’ approach to learning. As a result, this type of project stimulates interest and improves retention in freshmen students. Industry receives recognition through assisting and mentoring students and also having some of their parts used in national competitions. Finally, the university itself receives positive exposure at these competitions.
The direct involvement provides better understanding of concepts, better problem solving skills, and better communication skills for the students. Using these projects increases knowledge of control and power systems, makes use of computer drafting and instrumentation systems, and covers an alternative energy application along with engineering applications. These multi-dimensional, interactive projects help develop communication and teamwork skills, as well as modern modeling simulation and testing protocols. Students conduct internet research to help decide best performance and best cost issues.

There stands to be gained a sense of pride and satisfaction from completing a project from the first draft to crossing the finish-line on race day. It creates a winning situation for everyone involved. Capstone design projects should be more than a matter of meeting a program requirement; rather they should be a matter of creating an experience that students can use for years to come.

References


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