2006-1814: AN UNDERGRADUATE RESEARCH EXPERIENCE IN ENGINEERING TECHNOLOGY

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Abstract

To initiate the development of an autonomous vehicle to participate in the Intelligent Ground Vehicle Competition, a multidisciplinary undergraduate research course was established during the summer of 2005 within the Engineering Technology Department. This was the first time an undergraduate research component has been offered to students within the Engineering Technology Department at the University of Dayton. The course was conducted using an independent study format with several team meetings to monitor individual student progress and to provide collaborative feedback to the students. The participants were expected to perform activities related to both research and design.

The course layout, the final student designs and the course evaluations are provided in this paper. The instructor and student evaluations of the course did conclude that future implementations need to provide the students with more structure and guidance through the initial research phase to ensure the level of research being conducted is at the technology level and not the product level. Overall, the students left the course with an expanded appreciation for the research, design and analysis aspect of engineering.

1. Introduction

The Engineering Technology Department at the University of Dayton (UD) provides every student with ample applied learning experiences and encourages students to seek industrial experience either through co-op positions or internships. To provide students with a meaningful exposure to engineering research, an undergraduate research course was developed. While the engineering technology students at UD are familiar with engineering design at the application level, few are ever exposed to engineering research at the technology level.

It has been said that the role of the university is to transfer knowledge, generate knowledge and apply knowledge [1]. Most would agree that college courses are primarily geared at transferring knowledge using traditional lecture based courses. Within the UD Engineering Technology Department course projects and associated industrial experiences such as internships, coop positions and the senior capstone project provide students with the numerous opportunities to apply their knowledge through the engineering design process. The generation of knowledge is typically overlooked in the students' college experience. By introducing students to a research activity, they are provided an opportunity to generate knowledge and more importantly learn how to think individually.

There are multiple levels of engineering research including research at the system level, which is typically referred to as system integration, research at the technology level which investigates an individual technology removed from any applied contexts, and research at the theory level that is concerned with the development of new mathematical and scientific processes. While many engineering research projects are focused on the scholarship of discovering, engineering technology research is best focused on the scholarship of discovery [3].

The undergraduate research course developed in the Engineering Technology Department at UD uses an existing university course structure designated for undergraduate research along with the Intelligent Ground Vehicle Competition (IGVC). Mobile robotics projects such as IGVC have been widely used to promote research and design within engineering education[2]. The purpose of the IGVC is to offer a multidisciplinary design experience that utilizes state-of-the-art technology in the formation of an autonomously controlled vehicle. The competition includes three elements: an obstacle course competition, a navigational challenge, and a design competition. The development of a vehicle to compete in this competition is a very challenging student project that also tends to be highly motivating. For these reasons, it is an ideal candidate project for the research course.

2. Course Overview

There are several avenues for melding research within an undergraduate engineering technology curriculum including the formation of a special topics or independent study course, the organization of seminars covering research activities such as independent study, analysis of data, and presenting scholarly work, the inclusion of a scholarship component within an existing course such as the development of research reports, developing product innovations courses, using a scholars program with a required thesis component, and funding for undergraduate research assistants[3]. Each method for providing undergraduate research opportunities has its own advantages and disadvantages. However, it is clear that to fully engage students in the research experience there needs to be both a well formulated and motivating research project with set outcomes for both learning and scholarly achievement and some form of compensation for the students' time spent performing the work.

2.1. The SET398 Course

Each department within the School of Engineering at the University of Dayton has a course numbered XX398, which is used to provide course credits for undergraduate research activities. The credits earned in these courses count as technical elective credits. In the Engineering Technology Department, SET 398 course entitled "Research and Innovation Laboratory" provides students a meaningful experience with engineering research and related activities.

SET398 allows students to participate in the selection and design of technology, the investigation, collection and analysis of data and the presentation of research material. Within the course description, research can include, but is not limited to, developing an experiment, collecting and analyzing data, surveying and evaluating literature, developing new tools and techniques including software, and surveying, brainstorming and evaluating engineering solutions and engineering designs. The credits associated with this course range from 1 to 6 depending on the scope of the project and the level of effort required by the student.

Students' sign up for the SET 398 like any other course, however professor approval is required. Since the course is typically conducted as an independent study course and the material covered requires strong mastery of the engineering fundamentals, students who enter the course must be highly motivated and have demonstrated an ability and eagerness to learn. For the inaugural implementation of SET398, student selection focused on their interest in the subject matter being investigated and their demonstrated scholastic aptitude. The student's aptitude was measured using their current GPA, recommendations from their advisors and finally through a brief interview with the instructor to determine their ability to independently learn.

2.2. Course Structure

Many undergraduate research courses in engineering programs desire to provide a hands-on component to students who would otherwise have little working knowledge through the traditional lecture courses. Many research projects are industry sponsored and can be very helpful in providing students future employment opportunities[4]. Contrary to this position, the developed SET398 course is structured to provide engineering technology students an opportunity to broaden their understanding of specific technologies separate from their application. Providing such a learning opportunity for highly motivated and academically strong students can also demonstrate the benefits of pursuing a graduate level education.

The course is broken into three separate phases, each focusing on a particular aspect of the research and design process. During the first phase of the course, the students perform engineering research to investigate existing technologies that can be used for their particular design. This phase helps define the components of information that they can use during the design phase of the project. It is important to note that the students are not researching the technologies in an applied form. To prepare for this phase of the course, students are provided with initial resources lists including all the related engineering professional societies and their associated publications and suggested research methods.

The students, during this phase, must learn how to conduct a literature research of technical documents and how to interact with other engineers in search of technologies that can be used for their design solution. Unlike a traditional lecture course, the instructor is not a "tour-guide" walking the students through new concepts. Instead, the students are independently responsible for their learning experience. Each student is required to find and review at least six refereed publications and another four supporting technical documents. Supporting documents can include Internet articles or pertinent information from external contacts working in the field. The references collected are also required to be complementary of each other and form a coordinated and meaningful body of material.

The second phase of the course is the interim design formation. During this phase, students compile their research and formulate initial engineering designs including all references used. This design phase includes individual and group brainstorming sessions, focusing on developing novel implementations of the researched technologies. Students also perform product research during this phase. Students are required to submit an informal interim design report and to introduce their designs to the instructor and class for feedback.

The last phase of this course is the formation of the final design. Using the instructor and peer feedback from the interim design phase, the students finalize their designs. Additionally, each student must support their design decisions using various analysis techniques. A weakness that many engineering technology students leaving college have is in understanding the analysis portion of the engineering design process. The analysis aspect of the design process is perhaps the most critical step and one that relies heavily on the fundamental physics, mathematics, and base discipline specific principles underlying the engineering profession[5].

The SET398 course contained five formal meetings for all students to attend and two individual design reviews between each student and the instructor. The instructor was also available throughout the semester to answer questions. A total of three students were enrolled in the SET398 course during the 2005 summer semester. The students were from the Mechanical Engineering Technology (MET) Program, the Electrical Engineering Technology (EET) Program, and the Computer Engineering Technology (CET) Program.

Each student was paired with a specific research and design task where all the tasks, when compiled, would produce the core electrical, mechanical and computational architectures of the UD autonomous vehicle. The MET student was focused on researching and designing the mechanical chassis for the vehicle including its structural analysis. The EET student was responsible for researching and designing the power distribution and drivetrain systems. Finally, the CET student was responsible for the computational system design.

3. Project Results

Each student had some level of success in reaching their stated objectives for their research and design task; however, no single student was able to completely meet every objective. A factor in the students' ability to complete all their tasks was the shortened length of the summer semester and difficulties during the research phase.

The mechanical chassis research and design effort was assigned to the MET student who was required to provide not only the chassis design but also a 3D model of the design and its structural analysis. It was desired for the chassis to meet the minimum system size requirements as specified by the IGVC rules, provide a minimum weight for transporting purposes and to use relatively inexpensive materials and fabrication processes. The MET student was able to complete a final design and structural analysis; however he was unable to successfully develop a 3D model due to unfamiliarity with the software package used in the department computer labs.

The research performed by the MET student focused in three areas: automotive chassis design, structural analysis and materials and welding. The student used the structural analysis resources to supplement material from a machine design course to calculate the maximum load rating of his final design. The material research allowed him to determine the best materials and joints to use for strength and functionality. The chassis design material was not useful due to the simple nature of the autonomous vehicle's chassis. During the interim design meeting, a brainstorming session led to the concept of using a standard 19" rack subsystem as the central module as shown in the vehicle diagram located in Figure 1. This subsystem would provide a highly flexible, lightweight and rigid environment for storing the vehicle's electrical components and batteries.

The EET student was responsible for the power system and powertrain designs. He was able to develop a complete design and associated analyses. The power system design and analysis included a power budget and a system circuit which is depicted in Figure 2 for a system with a 30 minute runtime. The EET student properly specified the motor and controller requirements from desired performance targets. He was also able to find commercially available motor control hardware that met these design specifications. However, the EET student had difficulty in correlating his motor controller research findings with the motor controller to his final design.

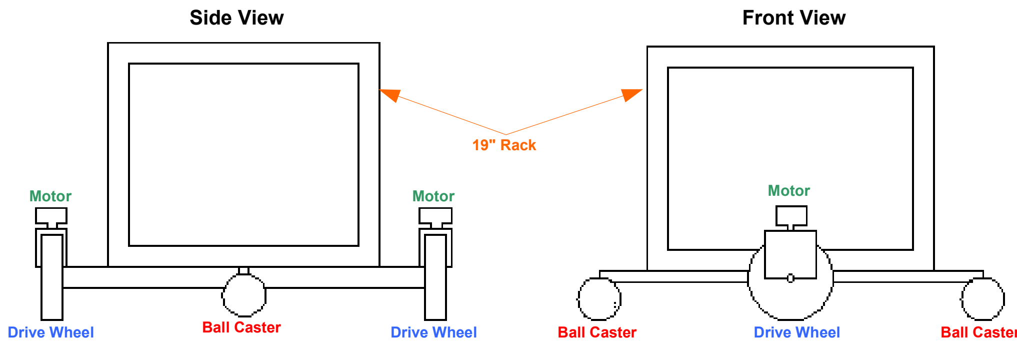

Figure 1: Preliminary vehicle chassis design developed from proposed specifications

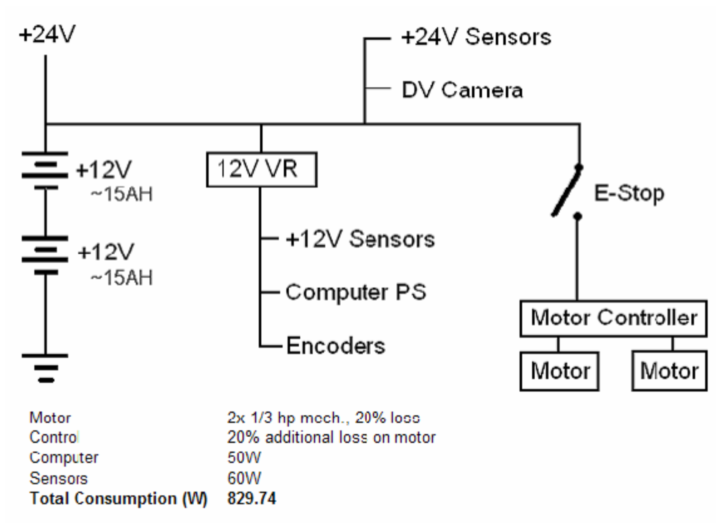

Figure 2: Proposed power distribution circuit and budget

The EET student struggled with finding research resources that focused on technology rather than products or applications of technology. Therefore, the motor controller used in the design was selected based on its ability to meet the desired performance requirements and not on its underlying technology. While this strategy did conclude with an appropriate design, the overall purpose for the technology research phase was circumvented.

Finally, the CET student performed the research for the computational system design. Before he was able to research applicable technologies, he first had to develop the required environmental specifications, performance specifications, and interface requirements for the computer system. To minimize system cost and implementation time, it was also desired to find a commercially available solution that would incorporate the desired technologies discovered through the research process.

A final specifications list was created with the best technologies to meet each specification. The proposed computational system layout, including all system interconnects, is located in Figure 3. The CET student discovered that there could be difficulties when trying to find a commercially available solution that meets the specified technologies. This portion of the design phase consumed the remaining course time and therefore no analysis was performed on the system. As part of the analysis phase, the CET student was to develop an algorithmic design for a system "health-monitoring" program that would periodically check the status of the computational system and its peripherals.

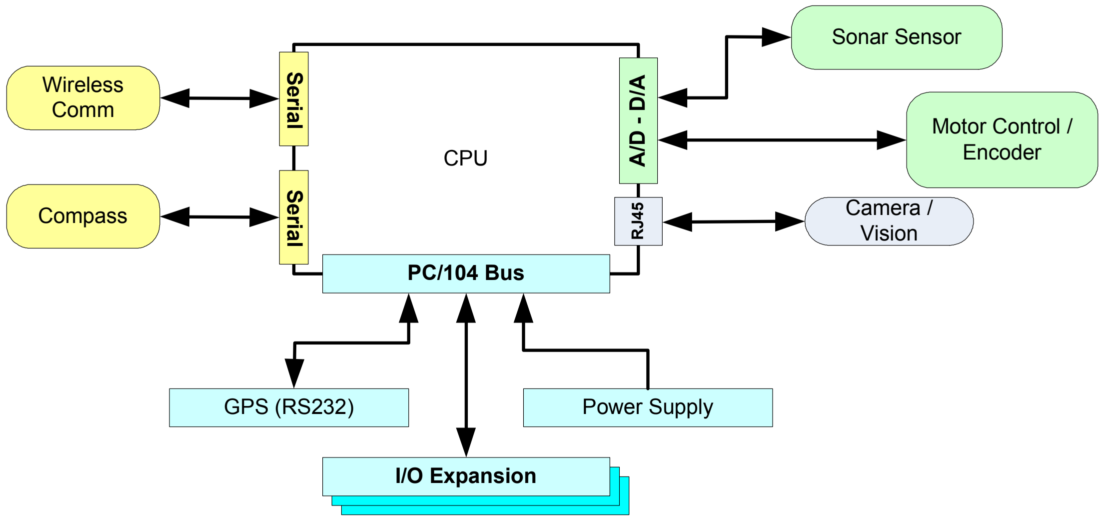

Figure 3: Proposed computer system with peripheral connections

4. Course Outcomes

Since the course used an independent study format there were only a few assessment points throughout the semester. The students were required to maintain an engineering journal throughout the research and design processes. This journal was submitted for review numerous times throughout the semester. Along with the journal, an interim and final design reports were also submitted.

The journal entries proved very useful in helping to maintain the students' level of effort and to ensure the students were on the correct path during the research phase. The students often felt overwhelmed during the research phase since they did not have prior experience of performing technology research. Through periodically reviewing the journals, the instructor was able to provide suggestions for research material and ensure the research being conducted was meaningful and applicable to the particular design objectives.

4.1. Student Feedback

Numerous positive outcomes associated with undergraduate research projects have been documented. Some of these outcomes include the students' ability to create something new that they feel is their own, their understanding of the importance in accurately recording and documenting all research and design work, and their understanding that knowledge can be gleaned from both successes and failures[1]. Another key outcome of an undergraduate research course is the students' ability to independently learn new material and think creatively.

To help realize how successful this course was at achieving these goals, a student survey was administered at the end of the semester to help identify the students' perception of the course, areas for future improvement in administering an undergraduate research course, and its impact on encouraging students to continue the learning process.

In commenting on how challenging the course was, all students agreed that the "open" structure of an independent study course proved very challenging. The self-discipline and required motivation is definitely an issue with any independent learning exercises. There was also a consensus that more frequent group meeting could have generated better results by helping to "force" along and keeping them better on track during the research phase.

One student mentioned that the research phase helped him gain confidence through interacting with other engineers and he was able to overcome some of his hesitations about asking questions. Another student commented on how the course helped reinforce the importance of teamwork when working on large engineering projects. This comment was surprising since the majority of the course work was performed individually except for the few groups meetings.

Another area that all students agreed on was a concern over how their performance was being evaluated given the open nature of the course. While there were set deliverables, it was not clear to the students how these deliverables would be evaluated. Furthermore, two students commented that intermediate feedback on course performance from the instructor would have been helpful.

4.2. Instructor Comments

Many instructors may consider that teaching an independent study course does not require much course preparation for the amount of learning that the students are ale to achieve since the students are primarily responsible for acquiring the necessary background knowledge needed to complete the project and meet the desired outcomes[6]. However, looking at the outcomes from the SET398 undergraduate research course, it is apparent that heavy instructor involvement, at least during the research stage, is critical.

The students tended to gravitate towards application specific research instead of looking at just the technology, which led to a longer research component and took time away from the design and analysis phases. While the importance of solid engineering analysis is sometimes neglected in traditional engineering technology courses, it was an important aspect of the research and design process in the SET398 course. Having the students perform a meaningful analysis of their design, and even research different analysis techniques can be an added bonus for performing undergraduate research. The application of course material to the analysis of an engineering solution can be very useful in demonstrating to students the importance of understanding the basic engineering principles.

5. Future Directions

The designs and research material generated in the SET398 course are being used as a basis for a multidisciplinary senior project that is tasked with implementing a fully functional autonomous vehicle. This design team is comprised of two mechanical engineering students, one electrical engineering student, one computer engineering student, and two electrical engineering technology students. The designs developed during the SET398 course will be very important in the successful realization of an autonomous vehicle.

This is the first senior design project to cross the engineering technology and engineering boundary at UD. The multidisciplinary nature of the IGVC has provided a great opportunity for not only encouraging technology research in the Engineering Technology Department at UD but also at demonstrating the complementary nature of the engineering and engineering technology disciplines, even at the collegiate level.

The Engineering Technology Department at UD desires to continue offering research experiences to undergraduate students. From the student surveys and instructor comments, it is clear that future offerings need to provide more assistance throughout the research phase. It is also clear that the students need more exposure to engineering analysis as a means of exercising their course knowledge and demonstrating how it can be applied to real-world engineering problems.

6. Conclusions

An independent study research course can be used to broaden student learning and help foster their capabilities to continue learning. However, in this course, the students require careful guidance throughout a research effort that is looking outside of applied technology and more at the base technology available. The use of mobile robotics is also found to be very valuable not only in providing a meaningful multidisciplinary engineering environment, but also in motivating students to learn.

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