Converting Single Disciplinary Capstone Projects to Interdisciplinary Experiences

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Abstract

This paper presents a plan for taking a single disciplinary mechanical engineering capstone project (designing and building a Mini Baja vehicle for operation over rough terrain and in deep water) and turning it into an interdisciplinary experience. An analysis is conducted on the potential benefits of including students with engineering management skills to assist with project management, and students with human factors engineering skills to design the vehicle cockpit layout including controls and displays. These contributions supplement the efforts of mechanical engineering students who design the frame, powertrain, brakes, suspension, steering, and flotation systems.

One of the most important benefits involved with participating in a senior capstone design course is the opportunity to interact with students from other disciplines in a forum where the contributions of each are necessary to successfully complete the project. In addition, adoption of interdisciplinary capstone projects meets the requirements set forth in ABET EC2000. Capstone projects that currently involve students from only a single discipline could greatly benefit from adoption of an interdisciplinary program. However, there are barriers that prevent this from occurring as often as it should. The most significant of these problems include the following: varying levels of interest among different departments in participating in an interdisciplinary project; differences in senior capstone and individual study project requirements for different academic disciplines; and the challenges of fostering a climate of mutual respect and cooperation between students from different academic backgrounds.

I. Introduction

When engineering students graduate and find employment in industry, they often find themselves working on teams of people with diverse backgrounds in terms of education and experience. Typically, a group is formed with a mix of people in order to solve a specific engineering challenge, and the unique skills and expertise of each team member are required in order to solve the problem. As a result, an ability to perform well on teams of diverse membership is a desirable trait for engineering graduates to possess. Participation on an interdisciplinary capstone project is a unique opportunity for students to develop and demonstrate this trait while still in school. Accordingly, ABET EC 2000 criteria specify functioning on multi-disciplinary teams as part of required engineering program outcomes [1].

Over the past few years, interdisciplinary capstone projects have become more and more popular as educators have begun to understand the great value that such projects offer to their participants. Unfortunately, many opportunities for interdisciplinary capstone experiences are missed as projects that have historically consisted of single disciplinary teams continue to draw upon students from a single discipline. However, by making participation on multi-disciplinary teams a requirement, the Accreditation Board for Engineering and Technology is mandating that schools reassess their capstone programs. This is likely to encourage educators to take full advantage of opportunities to bring together students with diverse backgrounds. The United States Military Academy's Mini Baja project is presented as an example of a single-disciplinary capstone project that could benefit from the skills and experiences of students from other fields.

II. Historical background of Mini Baja Vehicle Project at USMA

The United States Military Academy participated in the Mini Baja East competition for the first time in the summer of 1989. Since then, the team has competed every year for the past twelve years, with teams composed entirely of mechanical engineering majors.

Figure 1.Vehicle Preparation

Figure 2. Endurance Competition

The competition requires students to "design and build a prototype of a four-wheel, single seat, off-road recreational vehicle intended for sale to the non-professional weekend off-road enthusiast." [2] (See Figures 1and 2, above) The competition requires the submission of a design report and a cost report. Static judging includes scores for engineering design and penalties for safety violations. Dynamic events include Acceleration, Top Speed, Braking; Land Maneuverability; DeepWater Maneuverability; Power Pull; Suspension and Traction; and an Endurance Race.

As part of the required curriculum for a major in mechanical engineering, students at the United States Military Academy are required to take a two-course sequence consisting of a course in automotive power plants and a course in power-trains and vehicle dynamics. These courses provide the knowledge and skills necessary to apply the mechanical engineering design process to an automotive system.

Since Mini Baja Teams have been successfully competing for years with mechanical engineers only, it might seem that the skills and experience of other fields are not needed.

However, a close examination of the tasks required to design, build, and race the Mini Baja vehicle indicates that mechanical engineers are being required to perform tasks that are much more suited to completion by students from other fields. The two areas where the need for assistance from other disciplines is most readily apparent are in the areas of project management and human-machine interaction.

III. Opportunities for System Engineering Expertise

Students from the Department of Systems Engineering can choose from three different majors: information systems, engineering management, and systems engineering. The field of the most interest to a mechanical engineering capstone design project is engineering management. Students from this discipline are trained to, "Define, develop, plan, and prepare to implement the chosen engineering solution within a broad global and societal context." [4]

Although mechanical engineering students have been planning for the design, construction, and racing of Mini Baja vehicles for the past thirteen years, they are much less qualified to do so than there counterparts in the systems engineering department. Engineering management students are formally trained to perform project management and system integration tasks; mechanical engineers are not. Employment of systems engineers for project management has the potential to streamline the administrative process and make efficient use of the teams time and effort throughout the year in preparing for the competition. Proper project management could result in earlier completion of the design and build phases of the project, resulting in more time available for product testing and driver training prior to the competition.

IV. Opportunities for Human Factors Engineering Expertise

The Department of Behavioral Sciences and Leadership includes a human factors engineering program that explores the fields of human performance and human-machine interaction. Students study how the human body works, and how it reacts to stimulus. As a result, they are able to make recommendations on the design of controls, displays, and the layout of the vehicle cockpit.

Again, mechanical engineers have been designing controls and cockpit layouts for Mini Baja vehicles for years. Sadly, without the understanding of how the human body works, and how it responds to stimuli, cockpit design is often an afterthought. Design of controls is sometimes condensed down to whatever material was handy at the time the vehicle was being assembled. By employing students trained in human factors engineering, there is an opportunity to make a conscious, informed decision about human-machine interaction as part of the design process, rather than relegating such decisions to afterthought.

V. Barriers to drawing assistance from other disciplines.

Based on the opportunities described above, employment of students from fields external to mechanical engineering could provide a significant advantage in the performance of a Mini Baja team. The tasks necessary to complete the annual Mini Baja design process are detailed in table 1, below:

Mini Baja Project Required Task	Applicable Field
Apply the mechanical engineering design process to an automotive system [3]	Mechanical Engineering
Define, develop, plan, and prepare to implement the chosen engineering solution within a broad global and societal context [4]	Engineering Management
Apply knowledge of human performance to the total system design of human-machine systems [5]	Human Factors Engineering

Table 1. Required Tasks and Applicable Fields

It should be noted that the tasks listed in Table 1 come directly from the Course Objectives, Program Outcomes, and Program Goals from each of the respective engineering programs at the United States Military Academy. It should also be noted, as stated earlier, that for the past twelve years all three of these tasks have been accomplished by mechanical engineers out of shear necessity. Now the question becomes, "Why *wouldn't* the team be an interdisciplinary team?" Unfortunately, there are some real obstacles that tend to prevent interdisciplinary teams from forming. Understanding the nature of these obstacles is the first step in any effort aimed at removing them.

The first obstacle encountered in an effort to build an interdisciplinary team is the varying level of interest among different academic departments in participating in interdisciplinary projects. Faculty members from a particular department may not be interested in participating in a project hosted by another department. Fortunately, the most likely problem is ignorance on their part. If there is an opportunity to demonstrate the benefits of interaction with students from other fields, and an opportunity to contribute to a serious student competition (as described above), they are likely to become interested in participating with the project. With the advent of EC2000 criteria, faculty from other departments are likely to be highly interested in participating in interdisciplinary projects.

Another possible obstacle to developing an interdisciplinary team involves the differences in senior capstone and individual study requirements for different academic disciplines. At the United States Military Academy, student out-of-class time is at such a premium that students are not likely to be available to participate on a project that does not meet course credit requirements in support of their degrees. Participation on the Mini Baja project for mechanical engineering majors meets course requirements for a three credit hour individual study in the fall, and a three credit hour capstone course in the

spring. The two-semester project begins with identifying needs, planning for the design process, developing engineering specifications, and developing concepts during the fall semester. In the spring semester, the team develops the product (the Mini Baja vehicle) and races it in the annual Mini Baja East competition sponsored by SAE. [6] At the United States Military Academy, the engineering management and human factors engineering majors both include senior-level capstone projects; however, they are one semester only without the allowance for an independent study to facilitate year-long participation. Although this challenge is unique to USMA, it is possible that other academic institutions could have similar problems with student availability due to course credit. One of the advantages present in civilian institutions is that students may participate on a project for the purpose of broadening their experiences to strengthen their resumés. Typically, students at military academies are less likely to participate for this reason because they do not need to interview for a job after graduation. Possible solutions to this challenge vary: from an informal work-around, to a formal request for a change to curriculum requirements in order to give credit for two semesters of participation.

Once the two barriers described above have been overcome, the third challenge becomes readily apparent. Indeed, this challenge is inseparable from one of the primary benefits of participation on an interdisciplinary team – the students must contend with the fact that their various background experiences and educations will cause them to bring different priorities to the project, leading to development of different courses of action in solving the engineering challenge. This is where students on an interdisciplinary team have the opportunity to develop the ability to deal with these issues while still in school, providing them with a more complete preparation for these experiences prior to graduation. Also of interest, there are likely to be faculty members from each of the disciplines involved who have a strong interest in the progress of the project. These faculty members will also have to deal with the fact that the recommendations of the team members from their field will be heard by the team as a whole, but implemented only to the extent that they support the final design concept adopted by the team's leadership. The challenge of fostering a climate of mutual respect and cooperation between students from different academic backgrounds is one of the most important experiences that the students can receive by participating on an interdisciplinary team.

VI. Results of First Year Implementation Efforts

The potential benefits of giving engineering students an interdisciplinary experience make the option worthy of detailed study. During the 2000-2001 academic year the author explored this option in an attempt to transform the USMA Mini Baja Team into an interdisciplinary project, with the following results. Faculty members from the Department of Systems Engineering were eager to participate on the project; however, the lack of an individual study course in the engineering management curriculum precluded participation by their students during the first semester. During the second semester, systems engineers contributed their project management expertise to the team in order to meet requirements for the systems engineering capstone course. This allowed the team leadership (mechanical engineers) to focus more on the physical aspects of

design by relieving them of much of the management responsibility. For the 2002-2003 academic year, a change to the systems engineering curriculum will add an individual study course for the fall semester to facilitate system engineer student participation for project management for both semesters. It is possible that some sort of work-around may allow full participation in the remaining year under the current curriculum. Faculty from the Department of Behavioral Sciences and Leadership also expressed interest in participation, and were able to make human factors contribution to the Mini Baja team count for a course project requirement for two students during the fall semester, and their capstone course in the spring semester. These students made a number of recommendations concerning design and layout of the cockpit and design of controls for the vehicle.

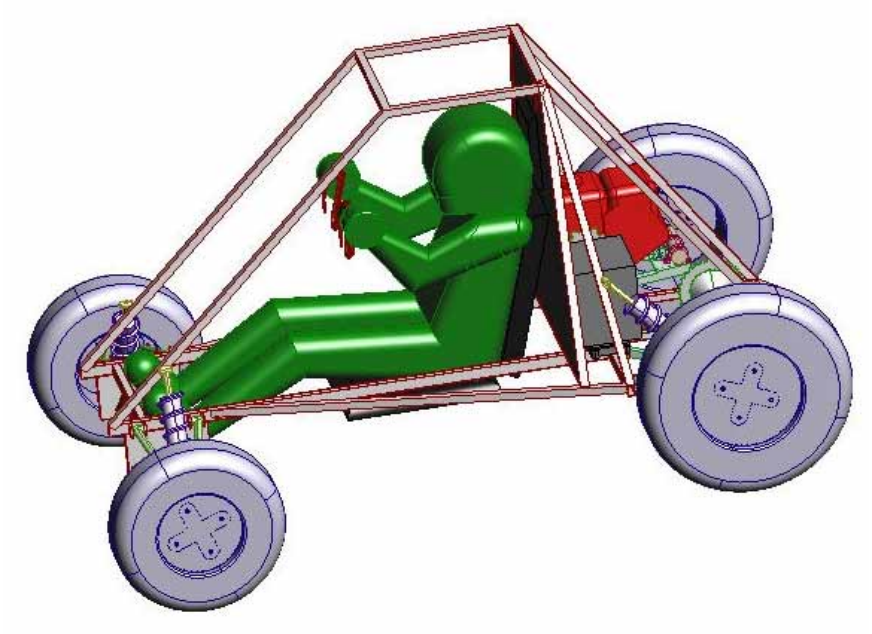

Figure 3. CAD Drawing of Mini Baja Vehicle with Driver

Based on anthropometric measurements of the team members and recommended seating orientation for optimal performance, the human factors engineers were able to provide dimensions and orientation for an aggregate "driver" for the Mini Baja vehicle. Modeling of the aggregate driver in CAD software provided immediate feedback to the team, which allowed team leaders to determine that the vehicle frame was too small to allow the driver to sit in the vehicle with the recommended orientation. Team leaders were able to use this information to adjust the frame dimensions prior to ordering materials and beginning construction. The value of integration of the human factors perspective into the design of this year's vehicle is difficult to express. At the very least it ensured a comfortable seating position for operating the vehicle; without human factors consideration in the design process, there would have been a significant cost in time and money to "discover" a cockpit layout suitable for comfortable and efficient operation. Due to a variety of constraints, the team leadership did not implement every recommendation; however, the students were able to make the design decisions on their

own, and the vehicle design was clearly improved by the contributions of the human factors engineers.

VII. Conclusions

The use of the Mini Baja team as an example of a capstone project that can benefit from expansion into an interdisciplinary team is intended to be just that – an example of what can be done. Depending on the project, any number of additional fields may provide a team with the expertise needed to solve an engineering problem. Many of the larger collegiate engineering projects such as Formula SAE and AUVSI Intelligent Ground Vehicle are already interdisciplinary projects. The intent with this paper is to show how even capstone projects that may have traditionally drawn from a single discipline can benefit from the formation of an interdisciplinary team. With the continued emphasis that the American Board of Engineering and Technology is placing on the formation of multi-disciplinary teams, this type of experience is likely to become the norm for undergraduate engineers in the years ahead.

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