

The Benefits of Involving Industry in Engineer Capstone Courses: A Case Study

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Students involved in capstone projects with support from industry gain a better understanding of the design process, have access to more resources, are more engaged, and ultimately produce a better product. At West Point within the Civil and Mechanical Engineering (CME) department students begin to learn the mechanical design process during their junior year. As they move into their senior year they begin to practice the design process. Ultimately they are required to demonstrate their ability to solve a complex real-world problem using the design process on a capstone project. That process can be enhanced with the external expertise offered by industry. Industry involvement in the capstone project benefits the students, the school, and industry. This paper uses an assessment of data from course-end-surveys of the students' perceptions on their performance as measured against program outcomes. A case study of a specific student capstone project will demonstrate the shared advantages of involving industry in capstone projects.

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Introduction

Undergraduate mechanical engineering (ME) students at West Point take a series of required design courses to complete graduation requirements. The first of these design courses is taken the spring semester of their junior year (Manufacturing and Machine Component Design). In this course they apply concepts learned in the basic core engineering curriculum to design specific machine components and subassemblies.¹ In the fall semester of their senior year they then take Mechanical Engineering Design. In this course they learn design as an iterative decision-making process in which they must meet the customers' needs.²

As a vehicle to teach the engineering design process students are given a small design project in which they must design a ring storage device to hold their recently-acquired class rings. They must determine who their customer is, what the customer requires, and design a storage device that satisfies their customers' needs. They produce a working prototype with detailed engineer drawings and present their product during a peer-reviewed presentation. This small design project is completed half way through the fall semester of their senior year.

The remainder of the fall and all of the spring semester is then focused on cadet capstone projects.

The projects are evaluated on the students' ability to follow the same engineering design process taught earlier. At West Point, students have the opportunity to select their capstone project based on their performance within the department. At the start of the students' senior year the department's senior faculty will compile a list of available capstone projects. Capstone projects become available through a variety of channels. Historically projects come from established collegiate competitions, faculty research, and needs of the Army and/or industry. Often, funding determines if a capstone project can be supported. One requirement is that the project must reinforce the design process for the students. One or two faculty members are then assigned as advisors to each project team.

The list of available capstone projects with the number of slots available is then published for the engineering seniors to review and decide which capstone project they want to join. Prior to the half-way point in the first semester all the seniors will meet in a large auditorium to choose their projects. The students are rank ordered according to an order-of-merit list based upon G.P.A. The number one student chooses his/her capstone first followed by the second student until all the capstone project slots are filled. When all the slots are filled for a project, it is no longer available for selection. One of these 2011 capstone projects will

be used as a case study to demonstrate why industry involvement is beneficial to students.

Case Study – Exoskeleton Project

West Point's soldier exoskeleton project was conceived as a solution to the military's problem of having soldiers carry substantial fighting loads over mountainous terrain. The competition was run by the U.S. Air Force Research Laboratory (AFRL) in a service academy competition between West Point, the Naval Academy, and the Air Force Academy. The West Point capstone team was limited to nine students. BAE Systems provided funds for the development of an exoskeleton-type device.

Prior to the cadets selecting their capstone project, the faculty project advisors and industry members from SpringActive and BAE Systems met to discuss a partnership for the remainder of the year. It was quickly apparent that West Point wanted to pursue an exoskeleton-type project as industry was beginning to bring to market several soldier exoskeleton-type solutions to similar soldier problems. These devices also had their origins from academia.³

In this meeting, the faculty and members from industry brainstormed a rough direction for the project. Each contributor committed to dedicating resources for the students. For example, BAE Systems promised to assist with the development of the soldier backpack that would be used to carry the soldier gear. SpringActive promised to assist with the controls, software, and electronics. The students were required to develop the design, manufacture all the components, and integrate everything together into a working package.

After the seniors selected their capstone projects, the faculty advisors were able to lay out exactly what was expected of the students and who was able to assist them. The team leader established three sub teams: design, controls, and power. He then designated that the design team work with BAE Systems and the controls team with SpringActive. He remained situationally aware through the use of scheduled in-class meetings.

The advisors' role in interacting with industry was to ensure that the cadets interacted appropriately with the industry partners in a way that was respectful of both their time and efforts. They ensured that the student team was prepared for information gathering sessions, teleconferences, and design reviews. Additionally, where required, the faculty arranged for the transfer of funds to assist in manufacturing and procurement of subsystems. SpringActive designed and built the team's electrical hardware at cost using an AMD processor, a

sensory ADC peripheral array, and two motor controllers. They also assisted the controls team in building the software model that would be used to run the exoskeleton. BAE Systems designed and built the backpack based upon the requirements provided by the students.

West Point didn't have the capability to fabricate a backpack or the time and resources to properly build a controller with the same capabilities as the one built by SpringActive. Additionally, near the end of the semester and once the project was almost complete, SpringActive had an employee travel to West Point and assist the controls team in integrating the program onto the controller and ultimately onto the exoskeleton.

Ultimately, the team built a working exoskeleton with the help of SpringActive and BAE Systems. The industry association allowed the team to focus largely on the design of the system as a whole along with the components of the mechanical system in particular. They saved the time and expense of designing two of the subsystems: the controller and the backpack. The student team had to work jointly with both industry partners. Design reviews were held as often as required to ensure the subsystems being delivered would seamlessly integrate with the system as a whole. This capstone project provided more opportunities, and thus more learning, compared to what would have been available without industry collaboration. In short, the students had an opportunity to participate and significantly contribute to the development of a relevant and cutting-edge research program. After completing and presenting the project the students felt an immense sense of accomplishment. They felt they were truly capable of performing state-of-the art research and designing real-world products.

Capstone Industry Involvement Advantages

During the semester and a half that the students worked on the exoskeleton capstone project, industry involvement brought obvious advantages. These advantages accrued to everyone involved with the project.

Student Benefits

1. Increased funds. Funding was provided by AFRL and BAE Systems. BAE Systems also provided the backpack free of charge.
2. External expertise. SpringActive assisted the students in designing and implementing their controls software. They used an algorithm that is not taught within the department's controls course thus exposing them to something different.

3. Increased student requirement to work with outside agencies/people. The students had to work across multiple time zones, use teleconferences, and communicate by email with their industry partners. They had real-world constraints forced on them identical to industry.
4. Increased sense of urgency and responsibility. The students didn't feel compelled to work for a good grade as much as they felt compelled to adequately perform for their "client."
5. Frequent external design reviews. The students were required to provide design reviews with their industry partners in a variety of ways as a method of integration. These reinforced concepts taught by the faculty advisors and offered an outsider's perspective on their design.
6. Exposure to real-world engineering. The students saw that their work was valued by industry and thus were able to see the link from education to industry.
7. Increased opportunities for internships. West Point has been able to send two students over the course of two years to SpringActive for summertime internships because of their involvement in capstone projects. These experiences have reinforced classroom instruction and prepared cadets for upcoming capstone projects.
8. Future job placement opportunities. While this isn't immediately apparent with West Point it may be more applicable at other schools.

Industry Benefits

1. Shared risk. Small companies like SpringActive must continually assume high risk in order to remain competitive and viable. Large companies such as BAE Systems tend to be more risk-averse on account of the greater potential for loss. Student capstone projects can assume high risk, help to explore the entire design space, and thus reduce the risk of industry failure. Together more opportunity for success emerges as more efforts are involved.
2. Future product development opportunities. The students provide a relatively inexpensive way of testing some basic ideas. BAE Systems and SpringActive are currently developing their own research from ideas gathered while working with the exoskeleton capstone project. The exoskeleton capstone project was used as a reference of previous work in a recent SpringActive grant proposal.
3. Proof-of-concept analysis. The students' development of a soldier exoskeleton demonstrated a new technique to actuate exoskeleton legs.
4. Collaboration with academia. BAE Systems and SpringActive have been able to establish

relationships with the West Point CME department. A professional affiliation exists between West Point and industry that is beneficial to both. Faculty members have been able to conduct academic research utilizing design concepts from SpringActive.⁴

5. Publishing scholarly articles. Industry representatives may serve as co-authors for peer-reviewed scholarly articles.
6. Increased opportunities for internships. Students involved in internships at SpringActive over the past two years have provided feedback during product testing that represents a student/soldier's perspective.
7. Societal contributions. SpringActive and BAE Systems have been able to strive "to increase the competence and prestige of the engineering profession."⁵ Academia's involvement in shared projects is considered prestigious by industry.
8. Tax benefits. By donating resources to educational programs, BAE Systems and SpringActive are able to use those donations as U.S. tax write-offs.

Department Benefits

1. Faculty members serve more of an advisory role. The students treated their industry partners as the subject matter experts within their respective fields. As such, industry is capable of providing more expertise to the students. The faculty advisors did not have the added responsibility to familiarize themselves with all the project's details. Additionally, the students would not ask questions of their industry partners until they had exhausted other means to find the answer.
2. Established industry relationships. Many annual project day evaluators and field trips for student classes have come from the relationships forged from industry-involved capstone projects.
3. Assists with accreditation. The West Point CME department annually invites industry representatives to review educational program outcomes, assisting the department in its mission to seek continuous improvement while providing a quality education. Traditionally many of these industry representatives come from industry-capstone partnerships.
4. Access to professional support. When project requirements exceed the capability of an undergraduate team or the capability of the department fabrication systems, industry partners are prepared to consult, advise, and/or take the lead for those requirements.

Course Outcome Comparison of Industry-Involved Capstone Projects to Non-Industry-Involved Capstone Projects

39 total responses, 17 for projects with industry, and 22 for projects not involving industry; 5-point Likert Scale ranging from 5 (strongly agree)

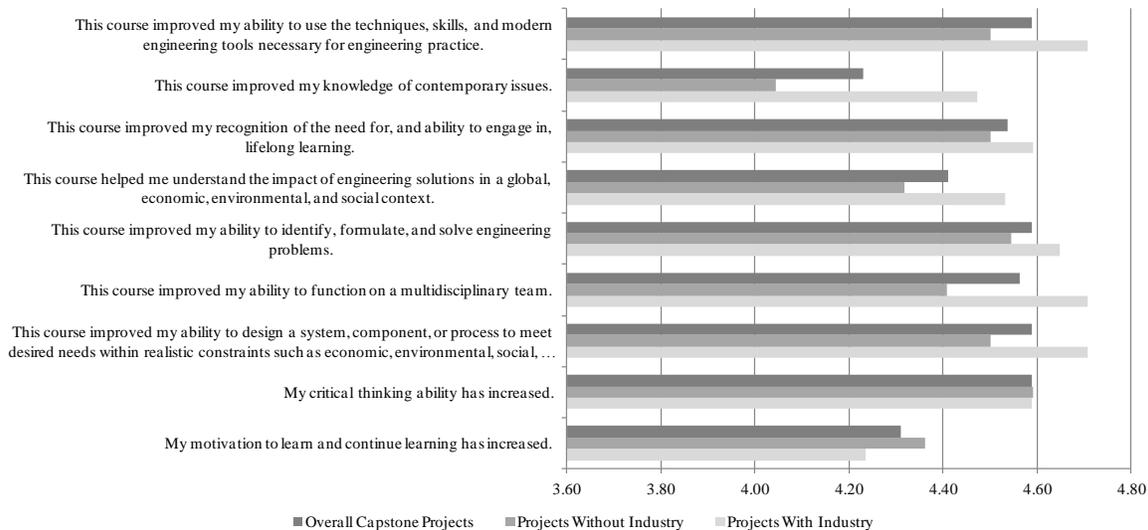


Fig. 1: End-of-course survey results for the senior capstone course.⁶

Conclusion

Comparing student perceptions of program outcomes with the various capstone projects helps bring an understanding of the advantages of involving industry in the students' capstones. Figure 1 illustrates the results from the end-of-course surveys of the capstone course. The comparison is made between projects that involved industry and projects that did not. Previous comparisons have been made comparing client-based capstone projects to collegiate-competition based projects.⁷

It is apparent that the difference between the students' perception of their critical thinking skills had no bearing on whether they were involved in an industry-related capstone project or not. In all other areas but one, industry-based projects had an advantage over the non-industry-based projects. Of note, the students involved in industry projects felt better prepared to function on a multidisciplinary team. They also perceived that their projects improved their ability to design systems and components and use their engineering skills more so than the other teams.

Students who work on industry-involved capstone projects gain a better understanding of the design process, have access to more resources, and develop a stronger sense of ownership on their project as compared to students not involved with industry. The benefits of participation extend beyond the students to the participating partner and the academic institution.

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