# Examining the Impacts of a Multidisciplinary Engineering Capstone Design Program

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Rogers joined the university in October, 2008 bringing with him 35 years of industrial experience. His career includes senior leadership roles in engineering, sales, and manufacturing in robotics, electronics, sensors, and controls industries. Throughout his career, Rogers has developed products using an innovative process consisting of multidisciplinary teams focused on understanding customer needs and converting them to commercially viable products and services. He brings this experience to the university where he leads the effort in developing company-sponsored, product-oriented Capstone design programs. As part of the mission of the Engineering Education Innovation Center (EEIC), Rogers has co-led the development of an ABET approved curriculum for a year-long Capstone experience. With a focus on providing students with a broader experience base, the multidisciplinary program applies teams of engineers, business, design, and other students to work with Ohio companies to help them be more competitive. Teams apply a company's core competencies to help develop new products and markets. This experiential learning emphasizes real-world problem solving, professional communication and ethics, teamwork, and implementation of a formalized design process. Additionally, Rogers has created the Social Innovation and Commercialization initiative by collaborating with business, engineering, and design colleges. Partnering with local non-profit organizations, teams define unmet problems working with people with various disabilities—problems that can be solved with an innovative product. The educational goal is to provide experiential learning with a social outreach. The social goal is to produce income to help non-profit partners become self-sustaining while improving the independence of people with disabilities. Rogers earned his PhD at the University of Massachusetts, Amherst focused on mechanical engineering and manufacturing. He has presented a number of industrial conference papers and holds several patents. He served as co-chair of the organizing committee for the 2012 Capstone Design Conference and is a member of the CDHub web development team. He holds the position of Professor of Practice at The Ohio State University.

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# Examining the Impacts of a Multidisciplinary Engineering Capstone Design Program

**Abstract**

The Engineering Education Innovation Center (EEIC) at The Ohio State University offers students through its Multidisciplinary Engineering Capstone Design Program, a broad range of opportunities for both engineering and non-engineering students to work directly with industry personnel on company-sponsored product and process design projects. The EEIC provides students an opportunity to apply their academics and practical skills to real-world problems while working on a multidisciplinary team. The program has been arranged as a two-semester design sequence beginning with a pre-capstone course for the first seven week of the semester. After completion of the pre-capstone course, students are distributed into teams and assigned a faculty advisor and an industry liaison to ensure success of the project.

The program is set to enrich the learning experience by providing the students an opportunity to work with industry while applying their academic background. The program covers all aspects of the engineering design process and helps demonstrate the importance of several critical professional skills such as; further developing the students' technical oral and written communication, develop professional and working relations between team members, project and time management, and ethics while developing a broad understanding of the relationships of business, engineering, and design elements. The program provides an opportunity for student design teams to contribute to real industry products by experiencing the complete design cycle which includes; defining the problem, creating the requirements, creating design concepts, developing detailed specifications, creating a detailed design solution, building a prototype, validating the design, refining the design, documenting the design process and identifying future recommendations.

An alumni-based survey was distributed to graduates who completed the multidisciplinary capstone program. The survey focused on the initial and potentially lasting effects of the learning objectives of the multidisciplinary capstone and their impacts on recent graduates' (1-5 years) careers. The survey includes both learning objectives of the program as well as industry focus areas in the initial interview process of the student. The results are used to support future development of the multidisciplinary industry-sponsored program, its learning objectives, and its efforts in providing a valuable and positive multidisciplinary industry-sponsored capstone experience for the students. This paper will address the quantitative results from the survey.

**Introduction**

Since the fall of 2009, the Engineering Education Innovation Center (EEIC) has been providing graduating seniors an opportunity to apply their education and professional skills to real-world engineering problems. The center has developed a capstone program for these seniors as a replacement for the discipline specific capstone experience or as a technical elective for their last two semesters at The Ohio State University. For the past three years, the EEIC has included many different colleges, such as business, engineering, humanities, and industrial design, into their capstone program.

The EEIC has partnered with over 50 industry companies to deliver design solutions to enable students to expand their professional skills working on real-world engineering problems. These

companies provided around 70 projects for 370 students who have completed the program. Examples of these projects include: a Corrosion Rate Measurement Tool, Explosive Decompression in Elastomers, Autonomous Tractor Backing Control, Automobile Aerodynamic Study, Zula Science Station Exhibit Design, Compression Vest for Autism, UPS Web Interface, and a Tray for Power Wheelchairs.

The Multidisciplinary Engineering Capstone Program challenges students to think outside the box and apply their academic and professional experiences to a real-world project. Companies define the projects and support them financially and through personnel support. The sponsor finds benefits in support of these projects through direct contact with students as potential employees and promoting their company on campus. As a secondary benefit, the company obtains a value-added outcome from the project from both the engineering design process and from the results of the project that the students follow.

When soliciting company sponsors, the objectives of the Multidisciplinary Engineering Capstone Program must be clearly stated to ensure the program's success. The focus of the program is to develop a student's skills to be a successful professional in the engineering field. Expectations for students, faculty advisors, and company sponsors are communicated to all participants.

Students are screened prior registering for the course through the submission of a professional resume and an interviewed to discuss the program and expectations. The screening process helps understand the students' integrity and motivation and will help increase the success of the projects. During the interview, the program coordinator evaluates the student's initiative, time management, leadership, teamwork, and communication skills.

After the interview, students are placed in one of the four sub-programs that the EEIC offers. These sub-programs include; Industry-Sponsored Projects, Industry-Sponsored Product Design Projects, Social Innovation and Commercialization (SIAC), and Joint Mechanical/Bio-Medical Projects. For industry-sponsored projects, students work with local companies to improve processes, reduce costs, or create new products and markets. The SIAC program has been a collaboration effort between five different colleges at The Ohio State University; College of Arts, Humanities, Engineering, Business, Medicine, and local non-profit organizations. The SIAC program designs and commercializes products for people with disabilities with the ensuing revenue helping the non-profit partner become more self-sufficient. The Joint Mechanical/Bio-Medical Project which has been a collaboration between the Colleges of Allied Medicine and Engineering. Within this sub-program, students design, build, and test biomechanical assistive devices.

Currently, most engineering students are placed in the Industry-Sponsored Projects. There are two different versions; industry project and a product design. Product design focuses on students designing a new or improved product for a company to sell or market. Students partner with industry and have the goal of reducing the costs and develop a product. Multidisciplinary engineering student teams will design, build, and test the product prototypes that will provide a potential solution to the problem statement.

The program offers students an opportunity to develop their project management, professional communication and presentation, and engineering ethics skills through the required deliverables from the project coordinator and faculty advisor. Students will complete a full design cycle from starting with a problem definition, to creating requirements and specifications for the project, design concepts, creating a detailed design solution, to building a prototype and validating the design.

The projects require participation by multiple parties to ensure success. A commitment by the company to maximize project value to the company and to help ensure an effective learning experience for the students is fundamental. The EEIC's program coordinator and academic advisors carefully select companies to assure the necessary collaboration and commitment. Faculty advisors are selected for each team and, in most cases, have some degree of technical familiarity with the project scope. Finally, commitment by students is required to work as a team, communicate effectively with clients and faculty, and provide the initiative necessary to produce effective results.

**Survey Design and Implementation**

An alumni-based survey was distributed to approximately 370 students who have completed the program. The survey focused on the learning objectives of the multidisciplinary capstone and their impacts on recent graduates' (1-5 years) careers. The survey was distributed through an online service to keep the results confidential and to provide real time data analysis. A lead-in statement was provided to inform the alumni's that their responses were voluntary and would be confidential with no personal identifiers collected. The alumni were also informed that his or her response would benefit the programs future development and its efforts in providing a valuable and positive multidisciplinary industry-sponsored capstone experience for the students.

The survey questions were focused on the programs objectives and compares how the program learning outcomes compare to career needs. The program's learning outcomes include:

Table 1: Program's Learning Outcomes[1]

| **Outcome Name** | **Outcome Definition** |
|---|---|
| 1. Perform Professionally | Students individually exhibit integrity, accept responsibility, take initiative, and provide leadership necessary to ensure project success as part of a multi-discipline team. |
| 2. Produce Quality Designs | Students collectively produce designs that meet important authentic performance requirements while satisfying relevant societal and professional constraints. |
| 3. Establish Team Relationships for Quality Performance | Students establish relationships and implement practices with team members, advisors, and clients that support high performance and continuous improvement. |

| | |
|---|---|
| 4. Manage Project Schedule and Resources | Students plan, monitor, and manage project schedule, resources, and work assignments to ensure timely and within-budget completion. |
| 5. Apply Knowledge, Research and Creativity | Students utilize prior knowledge, independent research, published information, patents, and original ideas in addressing problems and generating solutions. |
| 6. Make Decisions Using Broad-Based Criteria | Students make design decisions based on design requirements, life-cycle considerations, resource availability, sustainability, and associated risks. |
| 7. Use Contemporary Tools | Students demonstrate effective use of contemporary tools for engineering and business analysis, fabrication, testing, and design communication. |
| 8. Test and Defend Design Performance | Students collectively test and defend performance of a multi-discipline design with respect to at least one primary design requirement. |
| 9. Communicate for Project Success | Students use formal and informal communications with team members, advisors, and clients to document and facilitate progress and to enhance impact of designs. |
| 10. Pursue Needed Professional Development | Students individually assess and pursue personal professional growth in concert with project requirements and personal career goals. |

The survey was comprised of ten questions; eight multiple choice and two open-ended, free responses. The questions presented in the survey are shown below in Table 2.

Table 2: Sample of Survey Questions

Multidisciplinary Engineering Capstone Program Survey Questions:

1. What year did you take Engineering 659: Multidisciplinary Capstone Program?

2. What is your current employment status?

3. In what program did you earn your bachelor's degree?

4. Did you have any non-engineering students on your team?

5. Rate its importance to your CAREER (1-Extremely Important to 5-Not Important)?

a. Design and Conduct Experiments
b. Analyze and Interpret Data
c. Design a system component, or process to meet a desired need within realistic constraints
d. Function on a Multidisciplinary Team
e. Function on a culturally and ethnically diverse environment
f. Manage an engineering project
g. Identify, formulate, and solve engineering problems
h. Communicate effectively orally in presentations, meetings, etc.
i. Communicate effectively in writing letters, technical reports, etc.
j. Recognize the need for and engage in life-long learning
k. Use techniques, skills and modern engineering tools
l. Use computing technology

6. Rate its Contribution to your preparation resulting from your CAPSTONE EXPERIENCE (1-Extremely Helpful to 5-Did Not Contribute)?

a. Design and Conduct Experiments
b. Analyze and Interpret Data
c. Design a system component, or process to meet a desired need within realistic constraints
d. Function on a Multidisciplinary Team
e. Function on a culturally and ethnically diverse environment
f. Manage an engineering project
g. Identify, formulate, and solve engineering problems
h. Communicate effectively orally in presentations, meetings, etc.
i. Communicate effectively in writing letters, technical reports, etc.
j. Recognize the need for and engage in life-long learning
k. Use techniques, skills and modern engineering tools
l. Use computing technology

7. Did the Capstone Experience help . . .

a. Have a successful interview
b. Obtain your first job after graduation
c. Transition into your first job assignment
d. Provide career advancement opportunities

8. Would you recommend the Multidisciplinary Capstone?

9. Why or why not in regards to your answer in Question 8?

10. How could we improve the MULTIDISCIPLINARY CAPSTONE experience?

**Survey Response**

The Multidisciplinary Engineering Capstone Program has been in effect since 2007. Since then, approximately 370 students have participated in the program in fulfillment of their capstone

requirement or course elective credit. The survey went out to those 370 alumni students. The overall response rate was approximately 20 percent provides informative feedback for the investigators. SurveyMonkey's "Tips and Tricks to Improve Survey Response Rates[2]" was used to achieve a high response rate. SurveyMonkey reports that approximately 10 percent is an average response rate and 30 percent was being a very high average. The responses gathered were a meaningful mix of all disciplines and each discipline was well represented.

Applying a multidisciplinary approach to real-world problems, by simulating the industrial experience seemed to be a reoccurring theme amongst the students. Introducing the students to different colleges within The Ohio State University, provides them with an opportunity to continue to improve their problem-solving, teamwork, and communication skills with students from other disciplines. The Multidisciplinary Engineering Capstone allows students to work with other disciplines on a real-world engineering problem which can have multiple solutions. Allowing the students to be exposed to the program, helps the students understand the need to learn modern engineering techniques as well as the managerial side and the organization behind a project. Figure 1 below indicates the students' understanding of the importance of lifelong learning while in the program and the significant importance while in their careers.

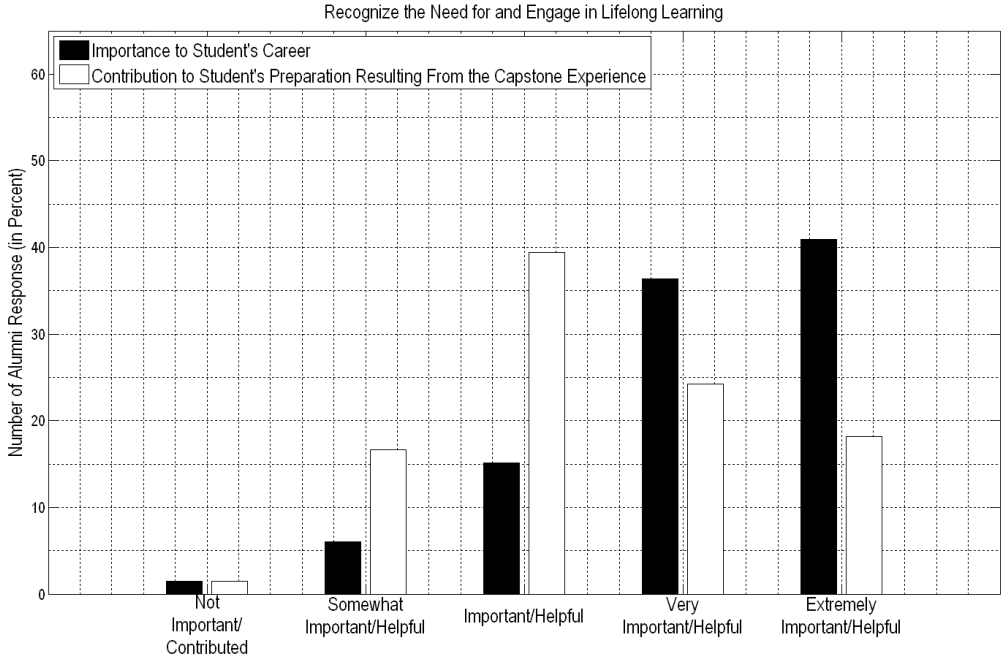


Figure 1: Question 5/6(j) - Recognize the Need for and Engage in Lifelong Learning Responses (in Percent)

By incorporating different colleges like business, engineering, humanities, arts, and industrial design, allowed the students to work with students from various academic backgrounds. The alumni students have shown that functioning on a multidisciplinary team was a key contributor in their career. This is shown in Figure 2 below that functioning on a multidisciplinary team had extreme importance in both the capstone program (54 percent) and while in their career (62 percent).

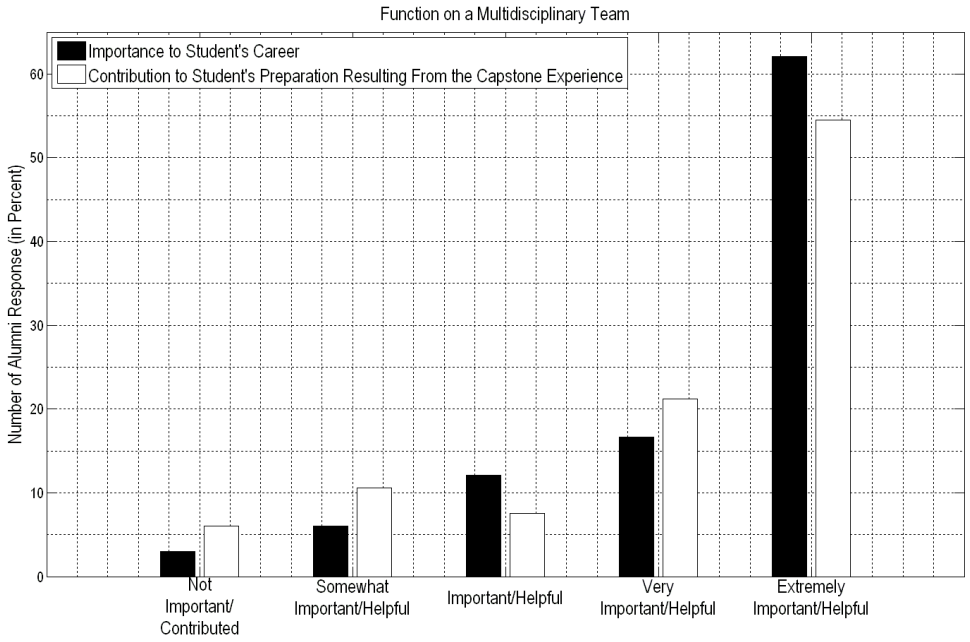


Figure 2: Question 5/6(d) - Function on a Multidisciplinary Team Response (in Percent)

A common response for both their career and while in the program was the need to communicate effectively during presentations, oral reviews, and with discussions between team members, project advisor, program coordinator, and the company. It was shown, in Figure 3 below, that communicating orally was 'extremely important' in the students' career with a 63 percent response rate.

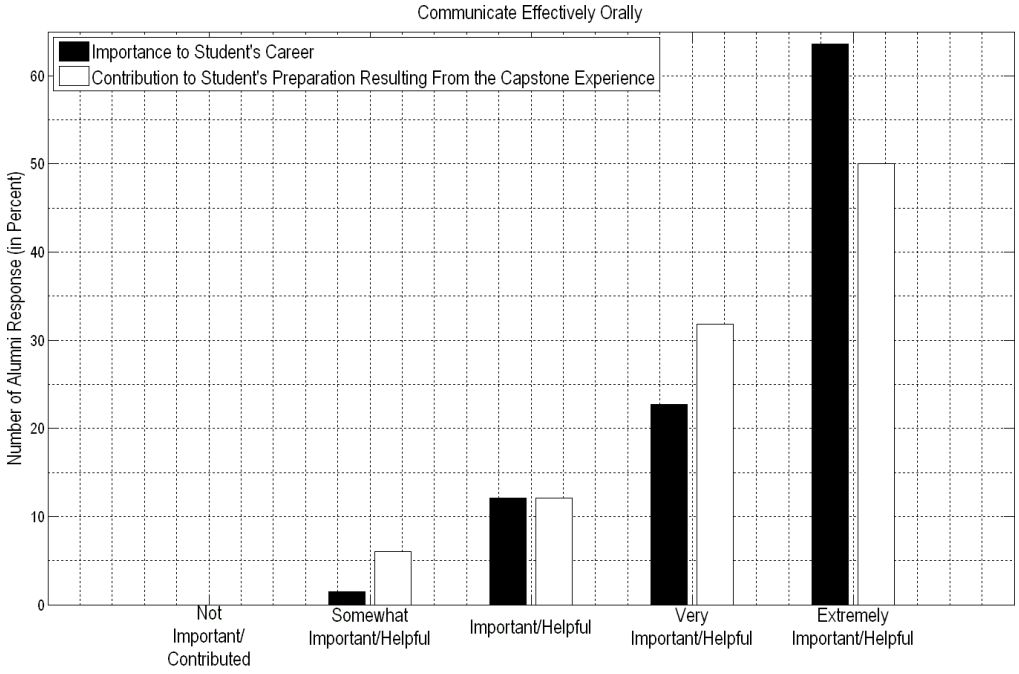


Figure 3: Question 5/6(h) - Communicate Effectively Orally Responses (in Percent)

The use of technical presentations provided an opportunity for students further develop their communication skills. Along with technical presentations, students have written deliverables that is required by the program. Students have reported that being able to communicate effectively in writing, being 'extremely important' in their careers, had a 44 percent response rate which can be seen below in Figure 4.

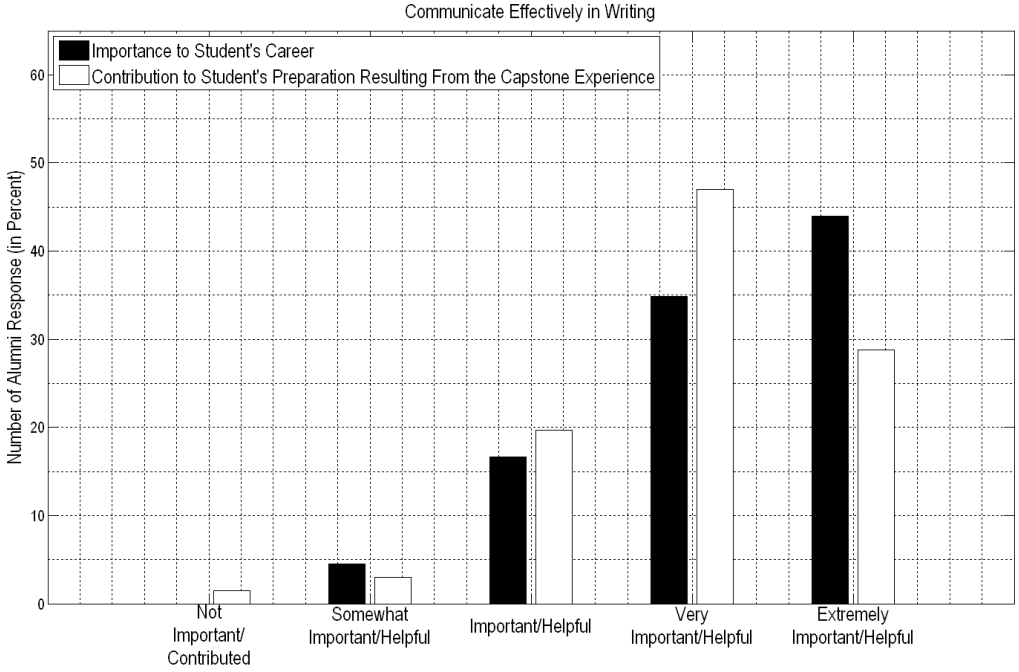


Figure 4: Question 5/6(i) - Communicate Effectively in Writing Responses (in Percent)

Students reported that they work with people with other non-technical backgrounds in their career and the opportunity of presentations and documentations helped the overall team communicate effectively.

The Multidisciplinary Engineering Capstone Program provides an opportunity for students to build technical skills such as Design and Conduct Experiments (Figure A-1), Analyze and Interpret Data (Figure A-2), Design a System Component (Figure A-3), Identify, Formulate and Solve Engineering Problems (Figure A-4), Use Techniques, Skills and Modern Engineering Tools (Figure A-5), and Use Computing Technology (Figure A-6). These results can be seen in the Appendix with their respectable figures listed.

It was interesting to note the low contribution of, functioning in a cultural diverse environment 'did not contribute' for nearly 23 percent of the students while in the program. While in their career, alumni students rated this the other way around. Providing a culturally diverse experience while in the program is important to address since this is shown in Figure 5 below the need to work with a culturally diverse team while within the work force.

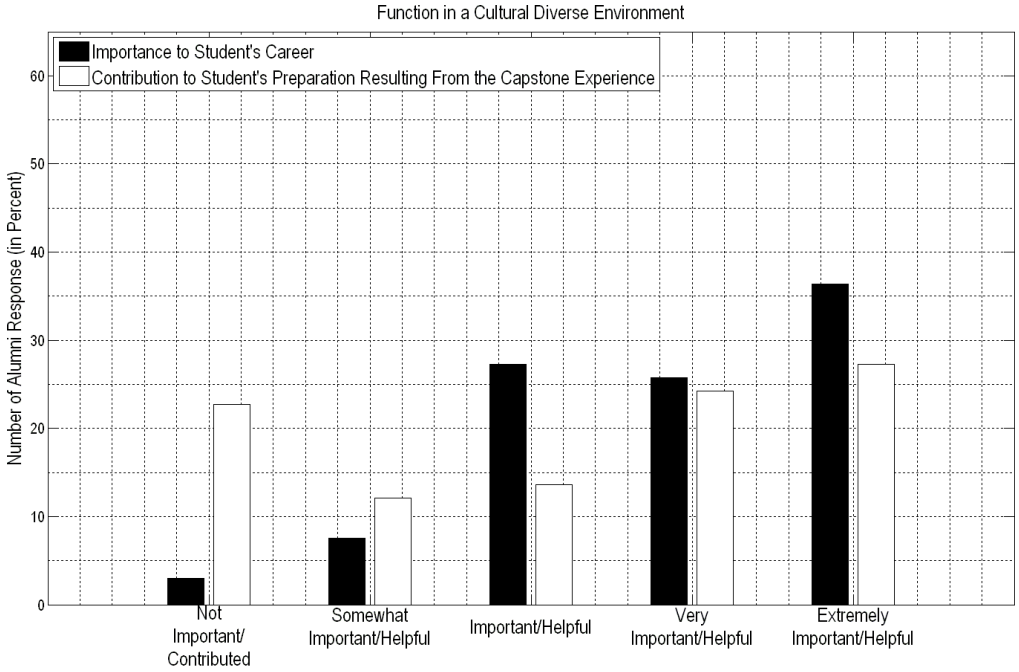


Figure 5: Question 5/6(e) - Function in a Culturally Diverse Environment Responses (in Percent)

Managing an engineering project rated fourth (out of 12) for students in the capstone program and it was of interest to see how high this scored for the alumni-students in their career. Managing their own engineering project was rated third highest in their career. This is indicated by Figure 6 below.

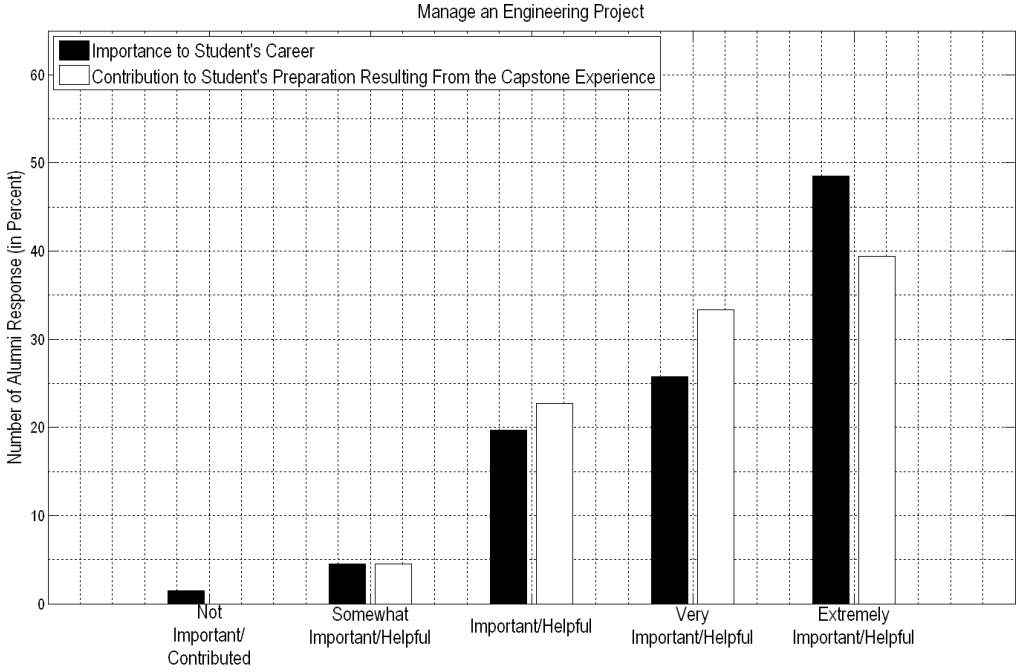


Figure 6: Question 5/6(f) - Manage an Engineering Project Responses (in Percent)

## Current and Future Work

Based on the survey results and informal classroom student feedback, improvements can be made to both curriculum content and delivery and project focus areas. The curriculum in the pre-capstone course can be modified to emphasize the importance of lifelong learning, communication, functioning in a diverse environment and analyzing/interpreting data. Curriculum changes will include a combination of in-depth discussions and exercises associated with these topics. In addition, the industry-sponsored capstone projects can emphasize these same topics through team meetings and assignments during the completion of the project.

To validate these survey results, a similar survey will be sent to all of The Ohio State University's engineering alumni to compare the effectiveness of the Multidisciplinary Engineering Capstone Design Program to the single disciplinary capstone design programs within The Ohio State University. The investigators will also distribute a survey to the industry sponsors that provides feedback about the Multidisciplinary Engineering Capstone Design Program and helps identify the effectiveness and preparedness of alumni in the workplace. This survey may also help identify areas within the program objectives that can be strengthened to help better prepare the college seniors for the work place. The investigators will examine the qualitative results for these results may benefit on further improving the program's success. The qualitative results may provide more insight on the students who considered the capstone experience a negative factor in their preparation for a career in engineering.

## Conclusions

The Multidisciplinary Engineering Capstone Program challenges students to apply their academic and professional experiences to industry-sponsored and supported projects at The Ohio State University. It gives the students an opportunity to develop skills with project management, professional communication and presentation, and engineering ethics, as well as directly work with industry.

A survey was sent to alumni-students who have participated in the program to further improve the program's performance as compared to what the alumni-students experience in their professional careers. The survey focused on the program's objectives and its impacts on early careers of students who have completed the capstone experience. The survey response rate was approximately 20 percent and all disciplines were well represented when compared individually. Overall, ninety-six percent of the alumni-students who completed the survey said they would recommend the program to incoming seniors.

## References

1. Rhoads, B., "Multidisciplinary Engineering Capstone Design Project I/II ENG659.01/.02 Program Guidelines", Engineering Education Innovation Center, College of Engineering, The Ohio State University.

2. P, Bennett. "Tips and Tricks to Improve Survey Response Rate." *SurveyMonkey Blog*. SurveyMonkey, 28 Mar. 2012.

3. Allenstein, J.T., Whitfield, C.A., Rhoads, B., "From the Industry to the Student: Project Management of an Industry-Sponsored Multidisciplinary Capstone Project", *Proceedings of the 2012 American Society for Engineering Education Annual Conference*, San Antonio, Texas, June 2012.

4. Whitfield, C.A., P.A. Schlosser, J.A. Merrill, E.A. Riter, and K. Agarwal, "Advanced Energy Vehicle Design-Build Project for First-Year Engineering Students", *Proceedings of the 2011 American Society for Engineering Education Annual Conference*, Vancouver, B.C., June 2011.

5. Dominick P.G., Demel, J.T., Lawbaugh, W.M., Freuler, R.J., Kinzel, G. L., "Tools and Tactics of Design" Wiley, John & Sons, Inc., November 2000.

6. Beer, D.F., McMurrey, D., "A Guide to Writing as an Engineer" Wiley, John & Sons, Inc., November 1997.

7. Whitfield, C.A., Freuler, R.J., Allam, Y., Riter, E.A., "An Overview of Highly Successful First-year Engineering Cornerstone Design Projects", *Proceedings of the 2011 International Conference on Engineering Education*, Belfast, Ireland, August 2011.

8. Courter, S.S., Millar, S.B., Lyons, L., "From the Students' Point of View Experiences in a Freshman Engineering Design Course", Journal of Engineering Education, July 1998.

## Appendix

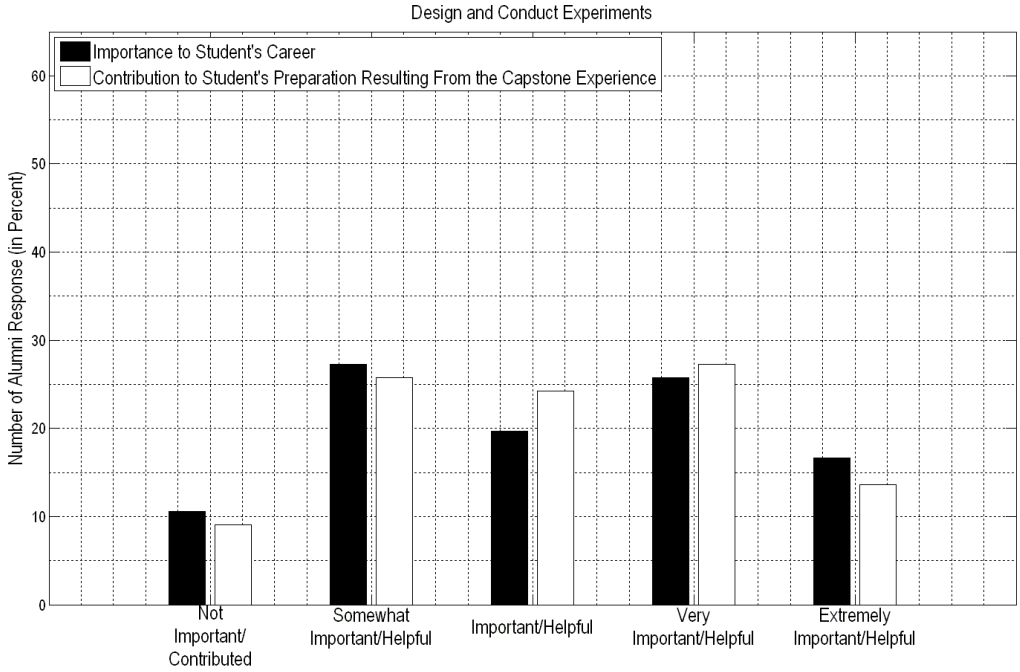


Figure A-1: Question 5/6(a) - Design and Conduct Experiments Responses (in Percent)

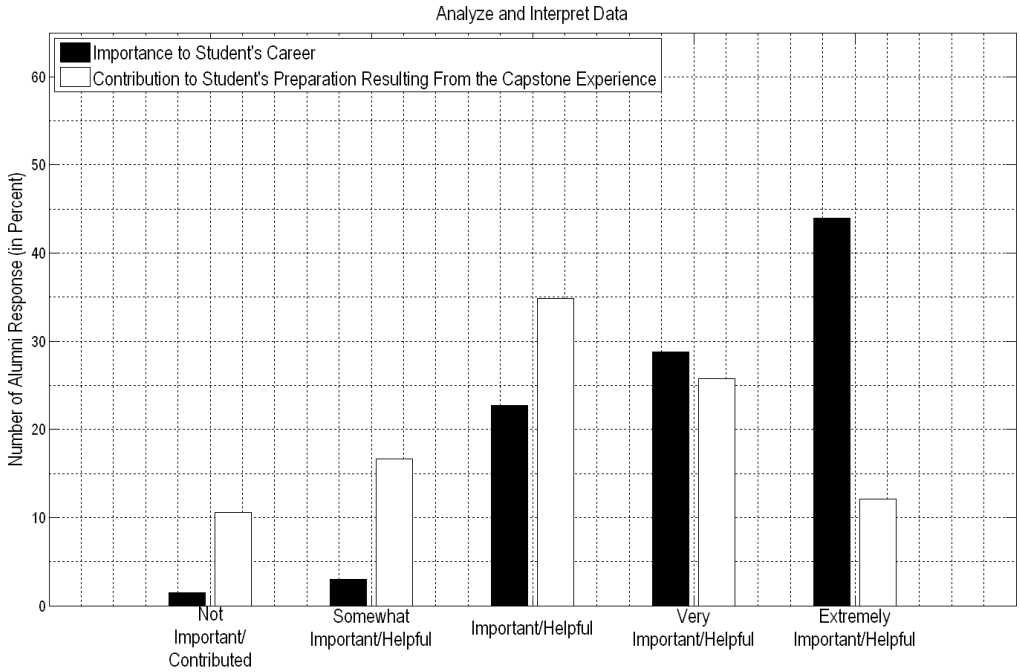


Figure A-2: Question 5/6(b) - Analyze and Interpret Data Responses (in Percent)

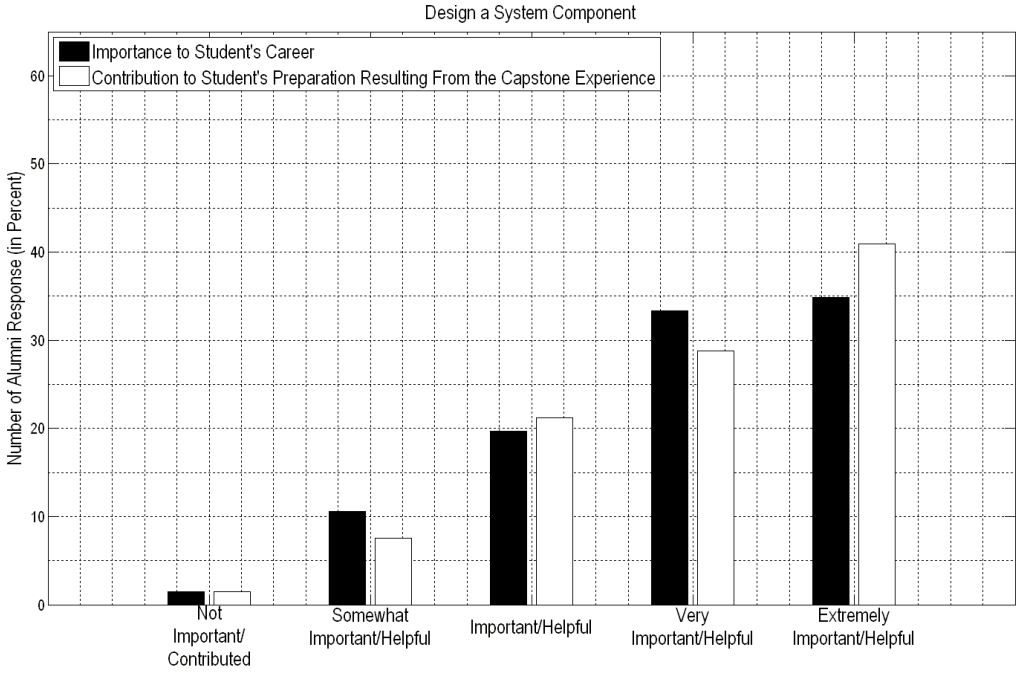


Figure A-3: Question 5/6(c) - Design a System Component Responses (in Percent)

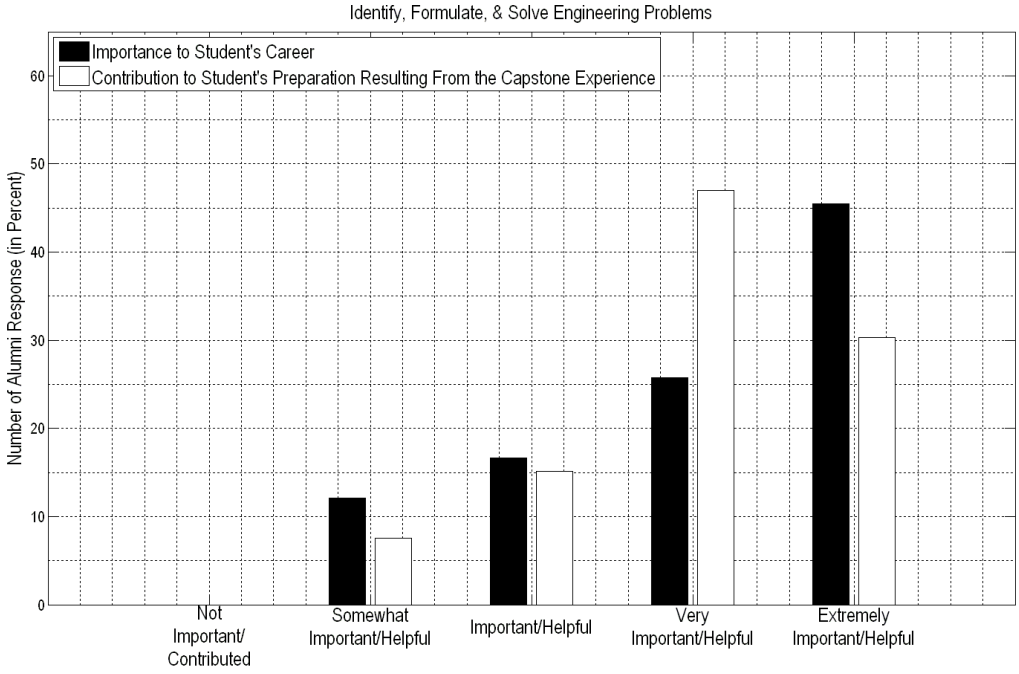


Figure A-4: Question 5/6(g) - Identify, Formulate & Solve Engineering Problems Responses (in Percent)

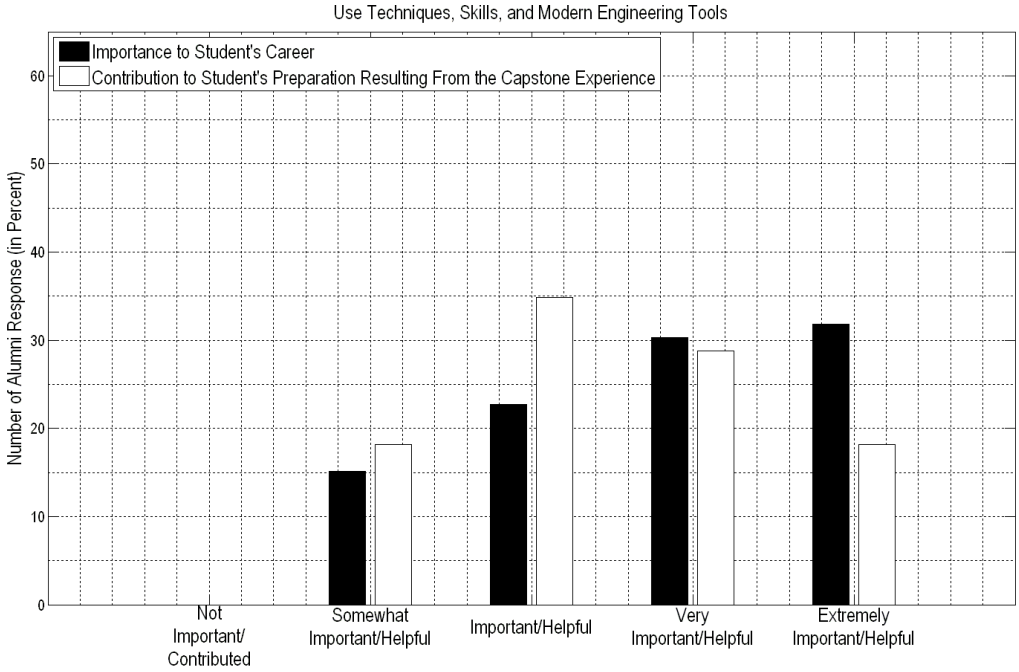


Figure A-5: Question 5/6(k) - Use Techniques, Skills, and Modern Engineering Tools Responses (in Percent)

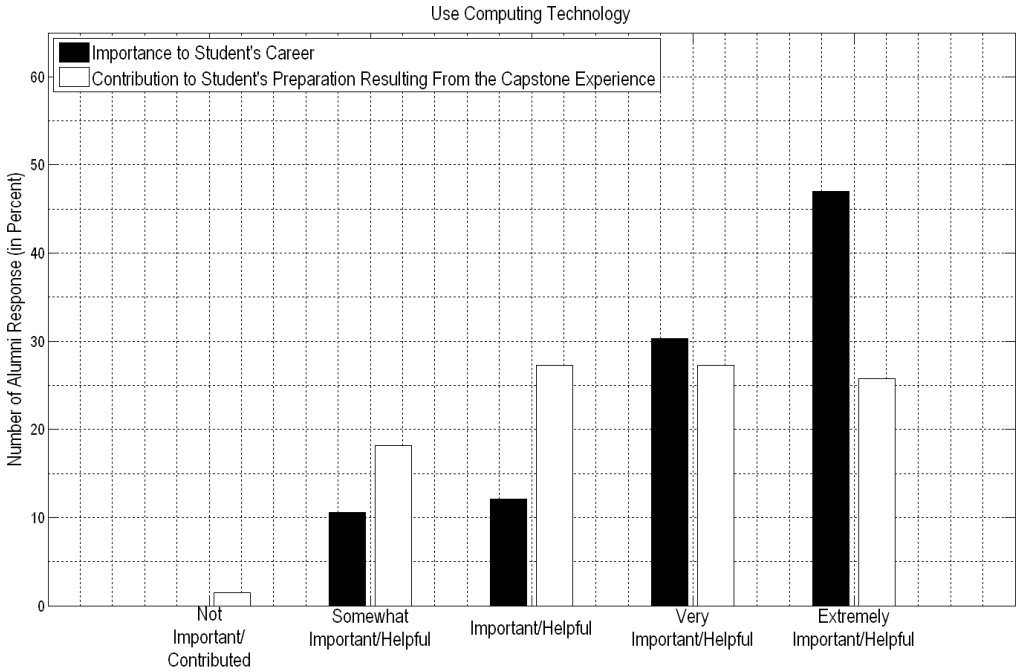


Figure A-6: Question 5/6(l) - Use Computing Technology Responses (in Percent)