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Industry Sponsor Valuation of a Multidisciplinary Capstone Program

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Industry Sponsor Valuation of a Multidisciplinary Capstone Program

Introduction

Preparing engineers for the future takes an understanding of industry expectations and the academic challenges to meet these expectations. "A strategy for realigning engineering education must be developed within the contexts of understanding the elements of engineering and recognizing the importance of constant communication with the public and engineering community stakeholders on the goals of education reinvention and the value of success."[1] Collaboration between academe and industry is crucial to prepare engineers to meet learning outcomes and the challenges of the future. To meet these challenges, engineering education must be realigned and a strategy must be developed to recognize the need to communicate with the public and engineering community stakeholders on the goals of education and the value of success.[1] According to Rick Stephens, retired Sr. VP of Human Resources and Administration from the Boeing Company, "Industry, society, and engineering schools can – and should – collaborate to ensure a sufficient number of such qualified and capable engineers to meet industry and society needs."[2] To meet the needs of both academe and industry, universities are incorporating multidisciplinary student teams to work on industry related capstone projects. Research has shown that multidisciplinary student teams produce better solutions than single disciplinary teams.[3] Past capstone design research surveys confirmed the trend to move from departmental (single disciplinary) teams to multidisciplinary teams.[4, 5, 6] Even though there is an increased interest to offer multidisciplinary teams, multidisciplinary capstone programs are difficult to create without college wide support and structure to foster this growth.[7]

The Ohio State University (OSU) offers students, through its Multidisciplinary Capstone Program (MDC), 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. OSU provides students an opportunity to apply their academics and professional and practical skills to real-world problems as a member of a multidisciplinary team. The program is a two-semester project design sequence. Based on the project scope, the coordinators form teams and assign a faculty advisor to ensure project success. The sponsor is vested in the program by assigning an industry liaison to participate in weekly student meetings, design reviews and coordinate student visits to the company. The program began in 2009 and has included over 20 disciplines, over 550 students and over 50 companies through the spring of 2014. Non-engineering students are involved through an engineering sciences minor program. The minor further promotes discipline diversity in the program while giving students academic credit.

The program recently concluded a three-year effort to obtain formalized responses from its industry-partners, program alumni and students who had just finished the multidisciplinary capstone experience.[8, 9, 10] The primary focus was on establishing rankings of the corresponding stakeholder's perspectives to the preparedness and importance of the program's learning outcomes and relevant accreditation board for engineering and technology criteria. The primary objective of this paper's research was to gather information from sponsors of the MDC to assess the educational effectiveness to prepare its students for their professional careers. To do this, the authors distributed a survey to 20 of its current and past industry sponsors. The survey focused on the ABET Criteria 3 (a-k) program objectives.[11] This paper addresses the quantitative results of the survey and compares industry identified needs to the MDC contribution to meet ABET. The research results were to identify characteristics that were important to early-career engineering professionals and to identify the most important learning outcomes to the capstone experience from an industry-sponsor perspective.

Multidisciplinary Capstone Program Structure

The multidisciplinary capstone experience is a two-semester course sequence with industry related projects defined by sponsor companies who support the projects financially and with company engineers working directly with the project. Projects include process and equipment design, energy and environmental improvements, and new product development. Students from all 14 undergraduate engineering programs have participated in the program. Programs include: aeronautical and astronautical, aviation, biomedical, chemical, civil, computer science and engineering, electrical and computer, engineering physics, environmental, food, agricultural, and biological, industrial and systems, material science and engineering, mechanical, and welding engineering. Students from other colleges also participate, and have included students from business, psychology, international studies, industrial design, dentistry, speech and hearing, occupational therapy, and food science. Many of the product development projects employ MBA students in the role of project manager.

The students follow a formal design process with design review phases that include problem definition, conceptual design, systems (or preliminary) design, detail design and final design. Each team has a budget that supports travel and prototype development costs.

Because the multidisciplinary capstone course is one of several options for senior engineering students, instructors can be selective when accepting students. They screen students through an application process that includes submitting a resume and application letter. Often, personal interviews are the deciding factor to ensure teams are formed with self-directed students. Students are asked to explain their interest in joining the program and to describe the contribution they expect to make to their team. During this process, the coordinators look for students exhibiting professional skills including time management, leadership, teamwork, communication, and initiative.

After the interview, students are placed in one of the three sub-programs that the multidisciplinary capstone program offers. These sub-programs include; industry-sponsored projects, industry-sponsored product design projects, and humanitarian projects. For industry-sponsored projects, students work with local companies to improve processes, reduce costs, or create new products and markets. The humanitarian projects have been collaborations between local non-profit organizations and an in-country local communities or universities.

Teams typically consist of three to six students matched to the needs and scope of the project. The sponsors present their project overview to all students and the students identify projects that they are interested in and apply to the project. The application process includes the student addressing academic and personal skills in which the project can benefit from in written form, and are submitted to the program instructors for review. They are assigned to a project based on their qualifications and interests, ensuring that each team has the disciplines necessary to match the project need. The company assigns an employee (typically an engineer directly associated with the project) to the team of students to act as a liaison, coach, and subject-matter expert. Capstone instructors recruit faculty advisors for each project, and are compensated by the program through project funds.

At the beginning of the experience, the students and faculty advisor will have a project kick-off meeting, typically at the industry's facilities. Throughout the project, the team will maintain weekly meetings with their advisor and company liaison. The weekly status updates are typically conducted through teleconference or videoconference meetings. At each major design review phase, the team will make a formal presentation to the industry and solicit feedback before moving on to the next design phase. The presentation is complimented with a formal written document addressing key elements and results of the specific design phase. The final deliverables include a formal final report that encompasses each major review phase, a complete project notebook including a complete working drawing package if applicable, and a functioning design prototype and test results. The students have the opportunity to present their designs to university, industry and the general community at an annual capstone design showcase. The showcase is organized by the multidisciplinary capstone program, and is offered to students from other discipline-specific capstone courses. Typically, there are over 150 teams from various capstone courses presenting at the showcase.

Survey Methods and Respondents

In autumn 2014, a survey was conducted with the program's current and past sponsors of capstone projects. The surveyed sponsors included company personnel who had direct contact with student teams during the project execution. When identifying sponsors and individuals, the authors selected subjects that had completed at least one capstone project prior to autumn 2014. The survey was sent to 20 company contacts representing 16 various sized companies. Multiple personnel from the same company were selected because of their experience with advising multiple projects and teams over multiple years. The surveyed personnel represented over 45 years of MDC involvement from autumn 2009 thru spring 2014. Figure 1 represents the percentage breakdown of surveyed representatives by the number of years they have been personally involved with capstone.

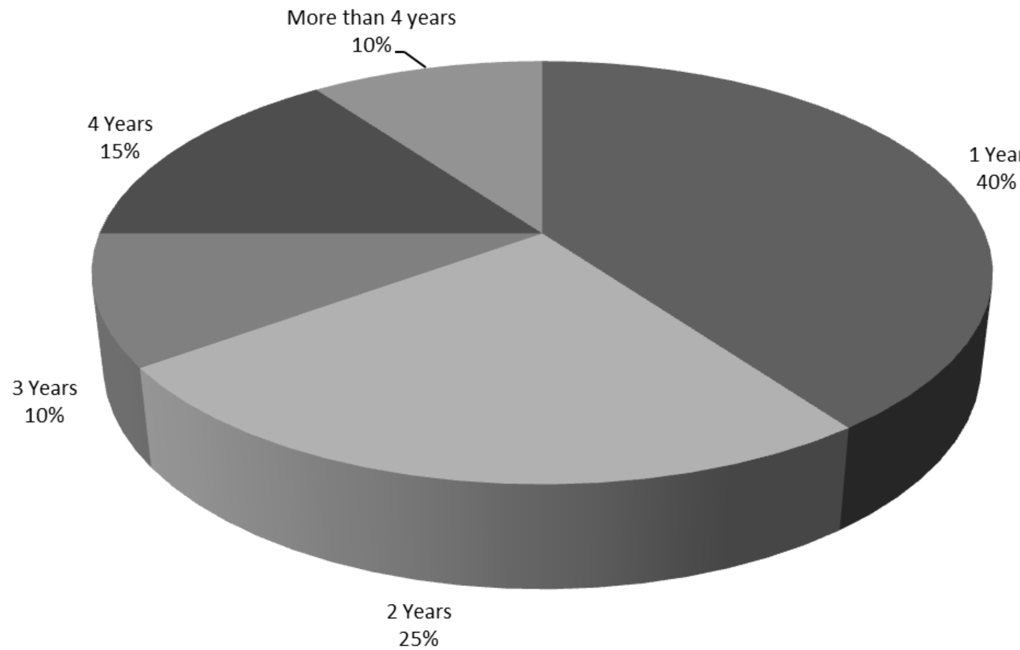


Figure 1: Surveyed Sponsors Involved with MDC

The company representatives were contacted thru an email inviting them to participate in the anonymous online survey using Qualtrics. The survey included general demographical questions related to the number of years and company personnel involved with capstone as well as their company's vested interests in participating in the program. This was followed by evaluating the MDC's program learning outcomes as it relates to an engineer's early professional career (< 5 years of experience) and the MDC program. Table 1 includes the program's learning outcome categories as related to ABET Criteria 3. Using a Likert scale, respondents were first asked to rate the importance of each category to an engineer's early professional career and then the importance of each category to the contributions of the capstone program. The survey ended with open-ended questions requesting improvements to the program. See appendix for the list of sample survey questions and responses to the open-ended questions.

Category	Related ABET Criteria 3
1. **Design and conduct experiments**	b
2. **Analyze and interpret data**	b
3. **Design a system, component or process to meet a design need with realistic constraints**	c
4. **Function on multidisciplinary team**	d
5. **Function on a cultural and ethnically diverse environment**	
6. **Manage and engineering project**	
7. **Identify, formulate and solve engineering problems**	e
8. **Communicate effectively orally: presentations, meetings, etc.**	g
9. **Communicate effectively in writing: letters, technical reports, etc.**	g
10. **Use modern techniques, skills and engineering tools**	k
11. **Use computing technology**	
12. **Recognize the need for and engage in life-long learning**	i

Table 1: MDC Program Learning Outcomes

The response rate for the survey was 50% with nine respondents fully completing the survey (n=9). Figures 2 and 3 include the results of questions relating to the number of years the respondent's company and the number of years the respondent has been involved with MDC, respectively. 45% of the respondents indicated that their company has been involved with MDC for more than 4 years. In addition, 56% of the respondents have personally participated in MDC directly for 2 years.

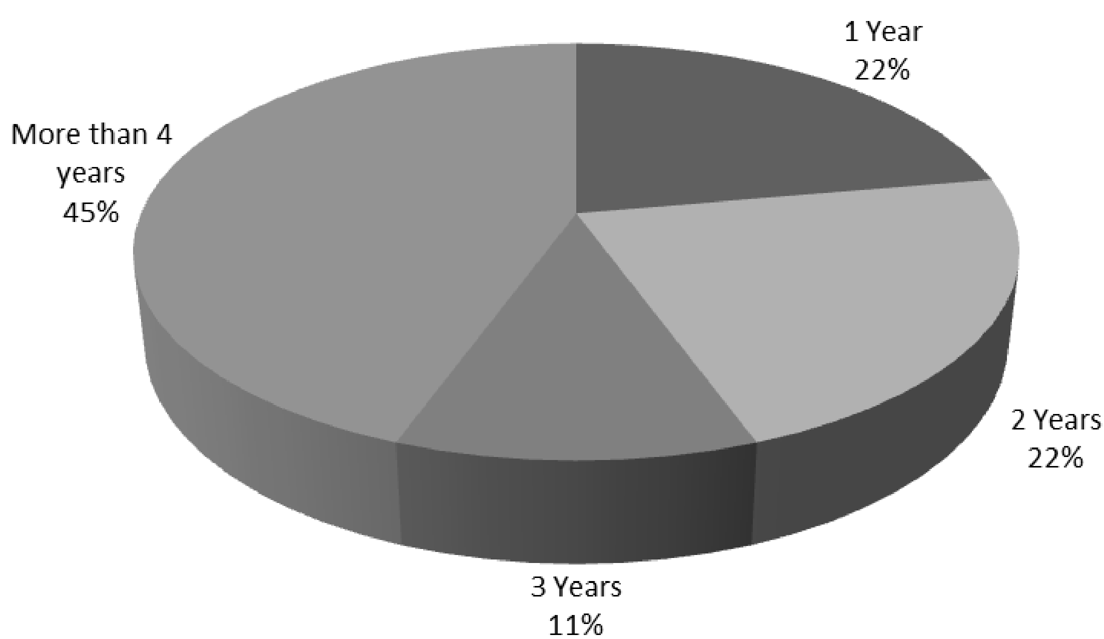


Figure 2: Surveyed Respondent's Company Involvement with MDC (n=9)

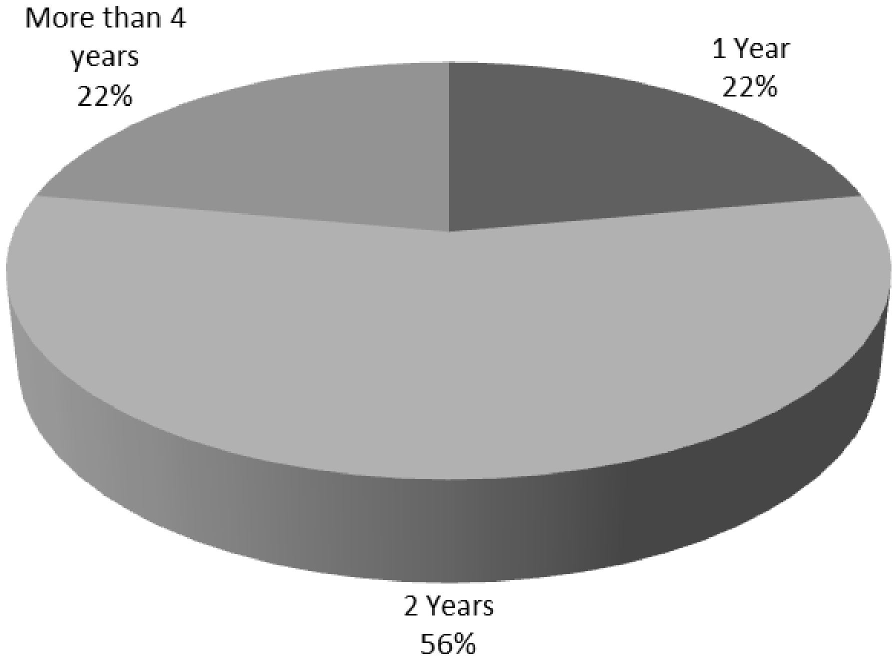


Figure 3: Surveyed Respondent's Personal Involvement with MDC (n=9)

Sponsors were asked to identify their company's purpose for partnering with the MDC program from a list of options. They were asked to select all that apply from the list of options, as well as identifying other reasons for getting involved with the program. Figure 4 shows the results with the top four reasons being educating students, solving a current company problem, promoting company's opportunities to students and identifying potential employees.

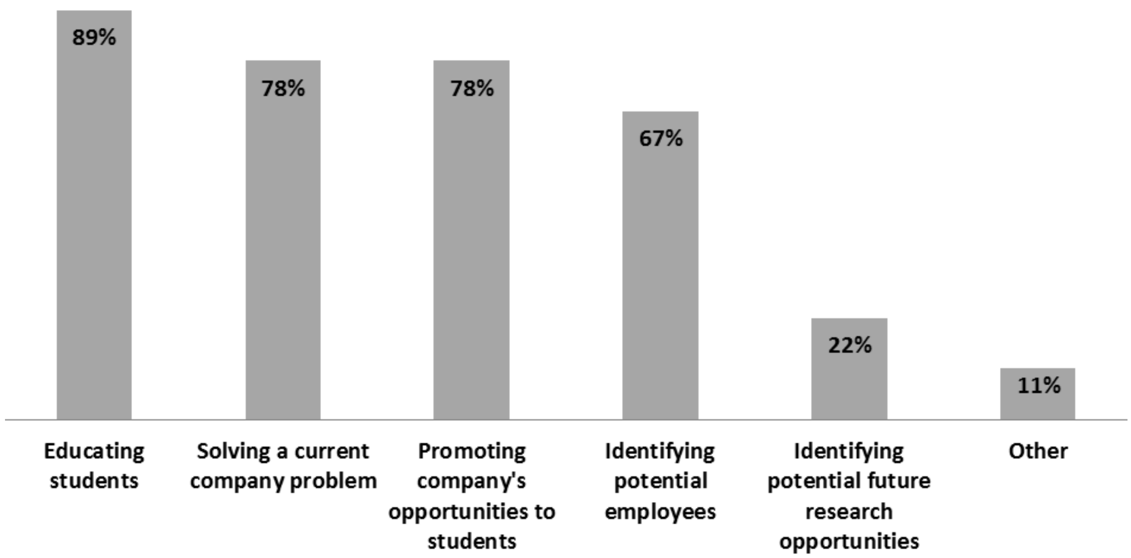


Figure 4: Surveyed Respondent Purpose for Involvement with MDC (n=9)

In addition to the provided options, one partner specifically indicated that involvement with MDC students provided an avenue to investigate new technologies and applications.

Survey Results and Discussion

This section details and discusses the quantitative results of the industry sponsored survey that addresses the program's learning outcomes. Sponsors were asked to rate the categories based on the importance to an engineer's early professional career. Early professional career was defined as an engineer with less than five years of experience. The sponsors were then asked to rate the same categories based on the contribution of the MDC program. The following figures and discussions compare these two question results. As one might suspect, respondents indicated that most of the criteria are important to an engineer's early-career as well as the contribution to MDC. Table 2 shows the results of the survey.

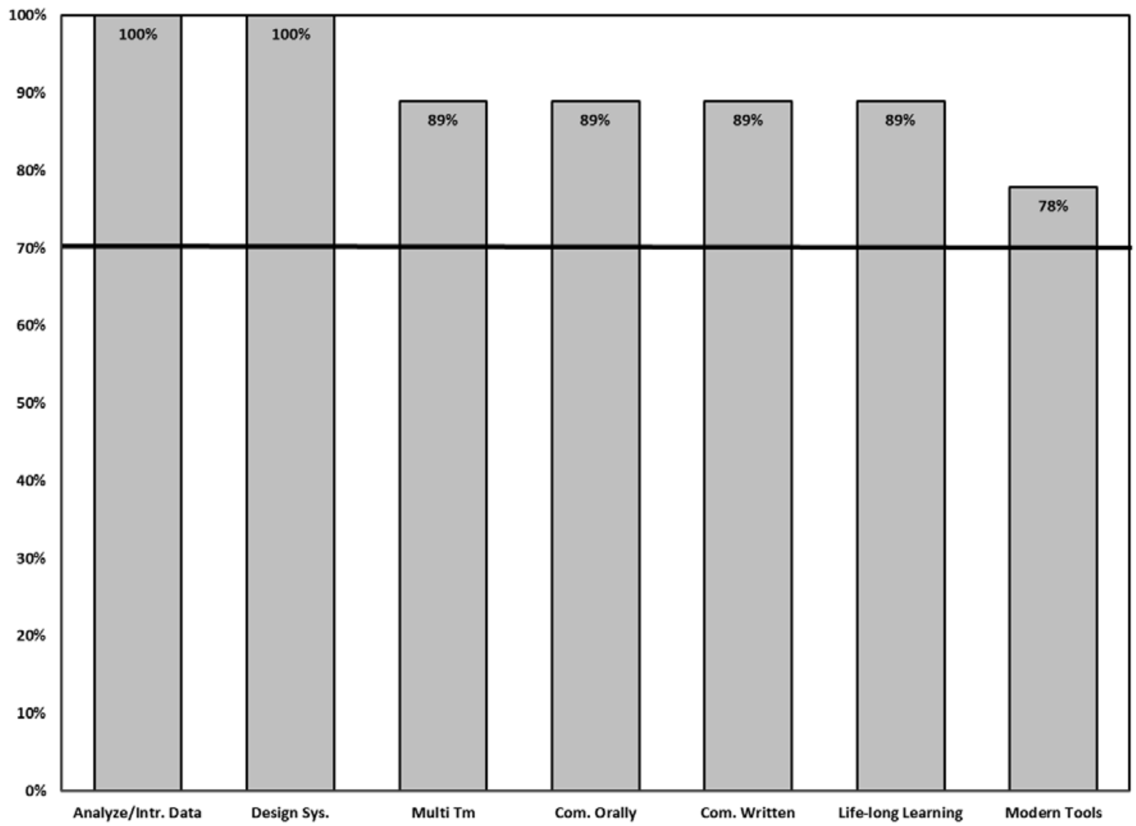
	Rate the following based on the importance to an engineer's early professional career (≤ 5 years)			Rate the following based on the importance to the contributions of the capstone program		
	Extremely Important, Very Important	Important	Somewhat Important, Unimportant	Extremely Important, Very Important	Important	Somewhat Important, Unimportant
Design and Conduct Experiments	67%	33%	0%	89%	11%	0%
Analyze and Interpret Data	100%	0%	0%	56%	44%	0%
Design a system, component or process to meet a desired need with realistic constraints	100%	0%	0%	89%	11%	0%
Function in a multidisciplinary team	89%	11%	0%	89%	11%	0%
Function in a cultural and ethnically diverse environment	67%	33%	0%	56%	33%	11%
Manage an engineering project	11%	67%	22%	56%	44%	0%
Identify, formulate, and solve engineering problems	67%	33%	0%	78%	22%	0%
Communicate effectively orally: presentation, meetings, etc.	89%	11%	0%	89%	11%	0%
Communicate effectively in writing: Letters, technical reports, etc.	89%	11%	0%	78%	22%	0%
Use modern techniques, skills, and modern engineering tools	78%	22%	0%	78%	22%	0%
Use computing technology	56%	44%	0%	67%	22%	11%
Recognize the need for and engage in life-long learning	89%	11%	0%	78%	22%	0%

Table 2: Industry Sponsor Survey Results (n=9)

To help differentiate between the category ratings, the authors selected a 70% importance rating as a threshold. An equal to or greater than 70% of the respondents selecting extremely important or very important rating was determined to be the most important criteria. If less than 70% of the respondents selected extremely important or very important rating for a category, the category was determined to be less important.

Importance to Early-career

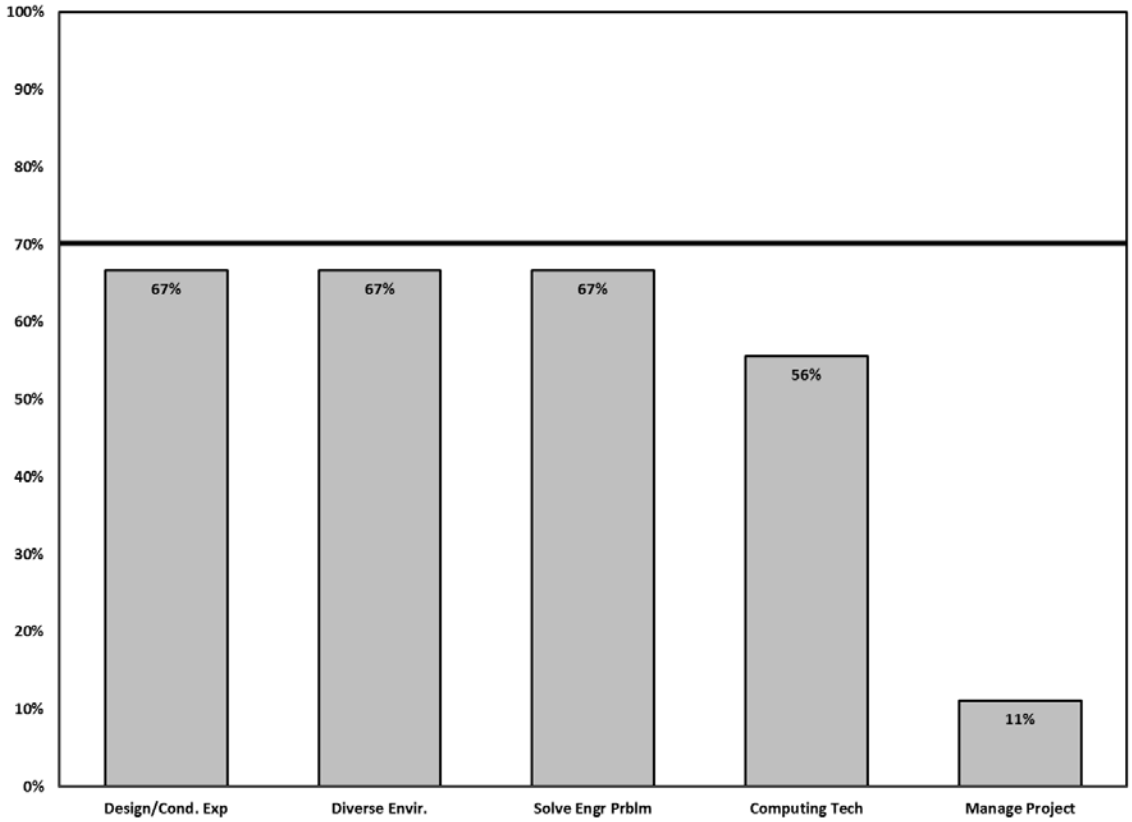
Based on the above described guidelines, respondents identified seven categories to be most important to one's early professional career. These categories include: analyze and interpret data, design a system, component or process to meet a design need with realistic constraints, function on a multidisciplinary team, communicate effectively orally, communicate effectively in writing, recognize the need for and engage in life-long learning, and use modern techniques, skill and engineering tools. See Figure 5.



*Combined Extremely Important and Very Important ratings

Figure 5: Respondents Early-career Important Criteria ($\geq$ 70%) (n=9)

The respondents identified five categories as less important to early-career engineers. They include: design and conduct experiments, function in a cultural and ethnically diverse environment, identify, formulate, and solve engineering problems, use computing technology, and manage an engineering project (Figure 6). In particular, only 11% of respondents rated managing an engineering project as extremely important or very important in the survey.

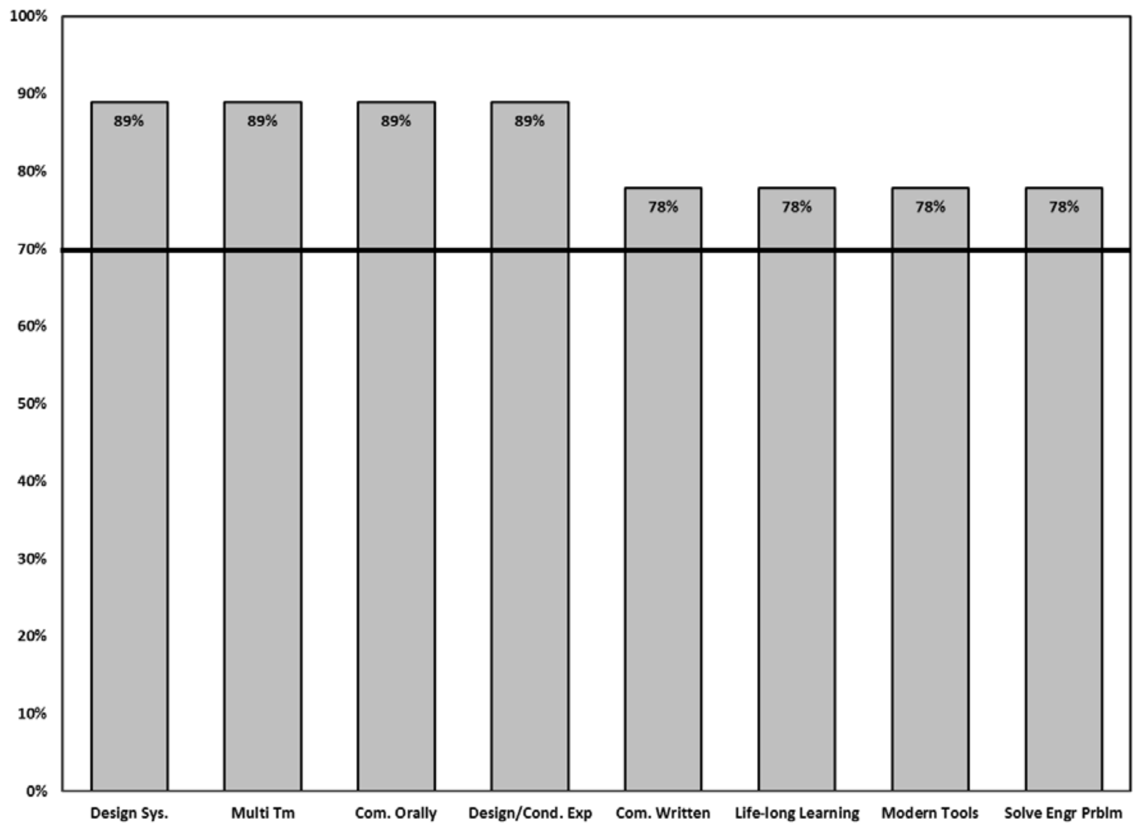


*Combined Extremely Important and Very Important ratings

Figure 6: Respondents Early-career Less Important Criteria (<70%) (n=9)

Contribution of MDC

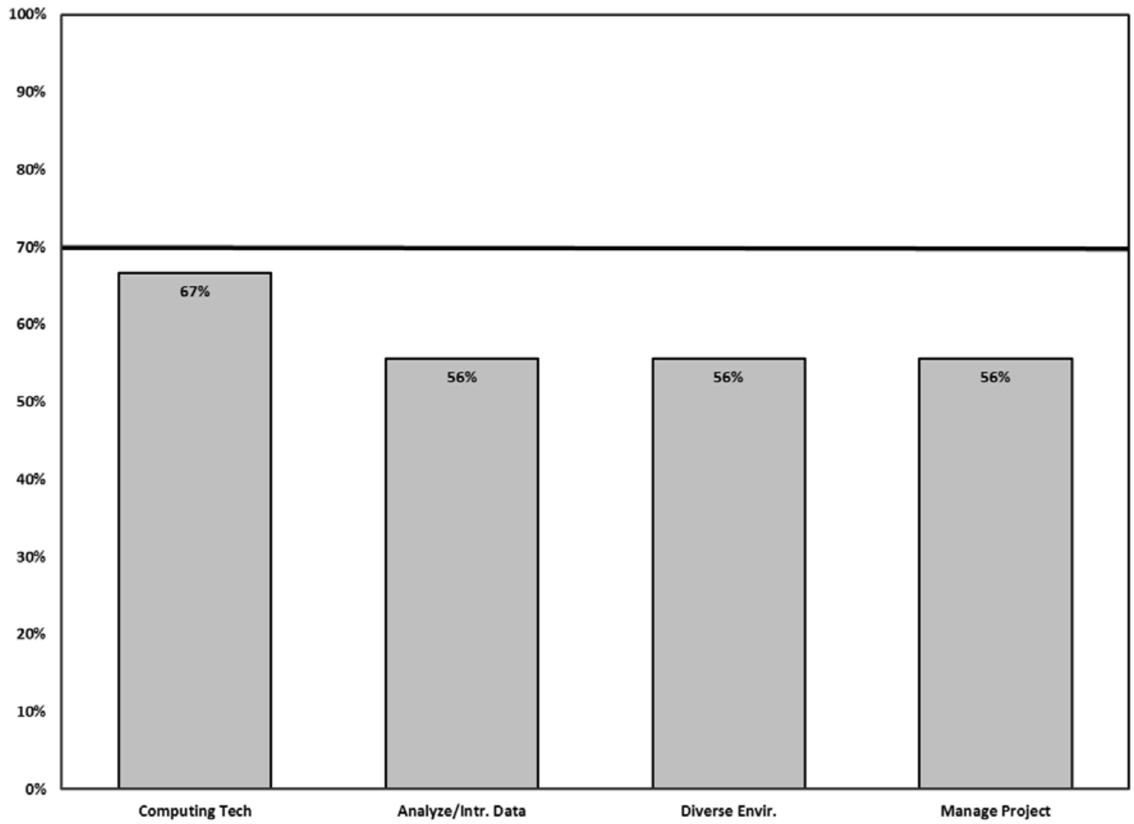
The sponsors were asked to rate the same categories based on the importance to the contributions of the MDC program. The respondents identified eight categories to be most important. These categories include: design a system, component or process to meet a design need with realistic constraints, function on a multidisciplinary team, communicate effectively orally, design and conduct experiments, communicate effectively in writing, recognize the need for and engage in life-long learning, and use modern techniques, skill and engineering tools, and identify, formulate, and solve engineering problems (Figure 7).



*Combined Extremely Important and Very Important ratings

Figure 7: Respondents MDC Important Criteria ($\geq$ 70%) (n=9)

The respondents identified four categories as less important to early-career engineers. They include: use computing technology, analyze and interpret data, function in a cultural and ethnically diverse environment, and manage an engineering project (Figure 8).

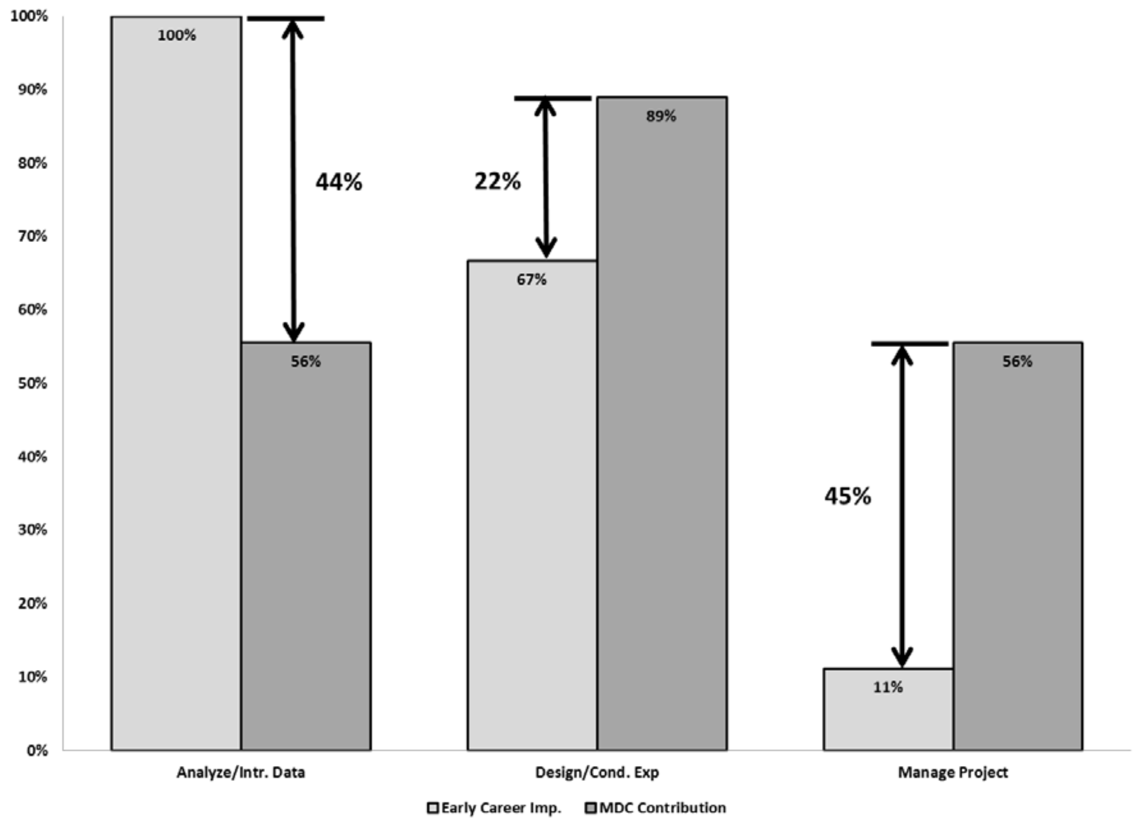


*Combined Extremely Important and Very Important ratings

Figure 8: Respondents MDC Important Criteria (<70%) (n=9)

Comparison of Importance to Early-career vs. Contribution of MDC

The following compares the respondents' results of rating the categories based on importance to early-career versus importance to the contribution of MDC. The authors identified 3 categories that had a significant difference in rating. These categories include: analyze and interpret data, design and conduct experiments and manage an engineering project (Figure 9). With regards to analyzing and interpreting data, the respondents indicated that there is a gap between (44%) the importance to an engineer's early-career and the contribution of MDC. Analyzing and interpreting data is very important to one's early-career while there is less importance placed from MDC. Conversely, respondents indicated that there is a higher (by 22%) contribution of MDC to designing and conducting experiments than when compared to the importance to an engineer's early profession. Managing an engineering project comparison resulted in a 45% difference with industry sponsors rating it less important in one's early-career than MDC's contribution.



*Combined Extremely Important and Very Important ratings

Figure 9: Respondents Early-career vs. MDC Important Criteria ($\geq$ 12%) (n=9)

Future Plans

The industry sponsor survey results indicated several MDC program outcomes as having a strong relationship between an engineer's early professional career and the importance to the MDC program. Based on these results, the authors identified one area of improvement that is directly related to the program. This area is to analyze and interpret data. Analyzing and interpreting data can be directly related to designing and conducting an experiment. The authors plan to emphasize the testing and validating phase of the capstone course by increasing the length of time that students can complete this phase on their industry sponsored project.

The survey results showed that managing an engineering project received the lowest percentage of respondents rating it as extremely or very important to an engineer's early-career. Since this category is a major emphasis in MDC, the authors plan to try to understand why by conducting follow-up consultation with its partners.

Conclusion

The program recently concluded a three-year effort to obtain formalized responses from its industry-partners, program alumni and students who had just finished the multidisciplinary capstone experience.[8, 9, 10, 11] The primary focus was on establishing rankings of the corresponding stakeholder's perspectives to the preparedness and importance of the program's learning outcomes and relevant accreditation board for engineering and technology criteria. The objectives of this paper's research were to gather information from sponsors of the MDC to assess the educational effectiveness to prepare its students for their professional careers. To do this, the authors distributed a survey to 20 of its current and past industry sponsors. The survey focused on the ABET Criteria 3 (a-k) program objectives. This paper addressed the quantitative results of the survey and compares industry identified needs to the MDC contribution to meet ABET. The results show that industry sponsors value the ability to analyze and interpret data; design a system, component or process to meet a desired need with realistic constraints; function in a multidisciplinary team; communicate effectively; and recognize the need for and engage in life-long learning as very important to an engineer's early-career ($\leq$ 5 years professional experience). In addition, the sponsors placed lower emphasis on the ability to manage an engineering project. The sponsors indicated that the MDC had strong contributions to students' preparation in the ability to design a system, component or process; function in a multidisciplinary team; identify, formulate, and solve engineering problems and recognize the need for and engage in life-long learning. Conversely, sponsors identified the program contributed less to the preparation in the ability to function in a cultural and ethnically diverse environment; use modern techniques, skills, and modern engineering tools; and use computing technology.

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Appendix

Table A-1: Sample of Survey Questions

1. How many years has YOUR COMPANY been involved with OSU's capstone program?
    a. 1 Year
    b. 2 Years
    c. 3 Years
    d. 4 Years
    e. More than 4 Years
    f. Unsure

2. How many years have YOU (personally) been involved with OSU's capstone program?
    a. 1 Year
    b. 2 Years
    c. 3 Years
    d. 4 Years
    e. More than 4 Years
    f. Unsure

3. What is your company's purpose for getting involved with OSU's capstone program? (Select all that apply)
    a. Educating students
    b. Solving a current company problem
    c. Identifying potential employees
    d. Promoting company's opportunities to students
    e. Identifying potential future research opportunities
    f. Other

4. Rate the following based on the IMPORTANCE to an engineer's early professional career (i.e. someone with less than 5 years experience): (1 – Extremely Important to 5 – Not at All Important)
    a. Design and Conduct Experiments
    b. Analyze and Interpret Data
    c. Design a system, component or process to meet a desired need with realistic constraints
    d. Function on a multidisciplinary team
    e. Function in cultural and ethnically diverse environment
    f. Manage an engineering project
    g. Identify, formulate, and solve engineering problems
    h. Communicate effectively orally: presentations, meetings, etc.
    i. Communicate effectively in writing: letters, technical reports, etc.
    j. Use modern techniques, skills and modern engineering tools
    k. Use computing technology
    l. Recognize the need for and engage in life-long learning

5. Rate the following based on the CONTRIBUTION of OSU's Capstone Program in preparing students for their early professional career (i.e. someone with less than 5 years experience): (1 – Extremely Important to 5 – Not at All Important)
    a. Design and Conduct Experiments
    b. Analyze and Interpret Data
    c. Design a system, component or process to meet a desired need with realistic constraints
    d. Function on a multidisciplinary team
    e. Function in cultural and ethnically diverse environment
    f. Manage an engineering project
    g. Identify, formulate, and solve engineering problems
    h. Communicate effectively orally: presentations, meetings, etc.
    i. Communicate effectively in writing: letters, technical reports, etc.
    j. Use modern techniques, skills and modern engineering tools
    k. Use computing technology
    l. Recognize the need for and engage in life-long learning

6. How can we improve OSU's Capstone Program in preparing students for their professional career?

7. How can we improve OSU's Capstone Program experience for sponsors?

8. Any other suggestions or comments?

Table A-2: Industry Sponsor Open-ended Survey Results

How can we improve OSU's Capstone Program in preparing students for their professional career?
Open their mind and provide more opportunities on industry experience
More frequent communication with the team seemed to improve results.
I went through a co-op work program and senior project that provided nearly 2 years of work experience. I am a big advocate of these types of work experience/projects for students. It helps provide focus to the type of career path a student may want for their professional career. If there was an introductory course for students early in their curriculum that would provide some of the foundation for this later Capstone project, I think that could be very helpful.

How can we improve OSU's Capstone program experience for sponsors?
The students are enrolled in this program for the education and experience. If the sponsors choose not to engage the students with challenging, meaningful projects, then the sponsors are not gaining all they could from this project. The Capstone program provides all of the tools and resources needed to help these students succeed.
Provide certain undergraduate student information such as their interests and education background to sponsors
The topic presentation at the beginning of the Fall semester could be done online through WebEx. All sponsors can present remotely and reduce the need of travel or presenting by faculty.
Before entering the OSU Capstone program, have students gain some co-op work experience and/or a Capstone type project earlier in their curriculum to help better prepare them for this experience with a company. They will have a better set of tools and more grounded expectations which would probably deliver higher level results to company

Any other suggestions or comments?
I really have nothing to suggest - the program is well managed and the students are generally very prepared.