Capstone Advisor Valuation of a Multidisciplinary Capstone Program

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Jacob T Allenstein is a graduate student in Aerospace Engineering at The Ohio State University in the process of a Ph.D. Jacob received his B. Sci in Aerospace Engineering in June of 2011 and a Master of Science (Aerospace Engineering) in December 2013. Currently, he is a graduate teaching associate (GTA) for the Engineering Education Innovation Center (EEIC) at The Ohio State University where he multi-manages both first year engineering students in the First Year Experience Program and senior capstone students going through the Multidisciplinary Capstone Program. Outside teaching, he is also a graduate research associate (GRA) with a research focus on the aerodynamics of jet engines, jet engine simulators, and jet engine testing facilities.
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Introduction
Real-world engineering projects typically lend themselves to multidisciplinary teams. Industry projects are multidisciplinary in nature and require interdisciplinary teams and interactions.\cite{1,2} Therefore, it is not surprising that many universities have started to offer multidisciplinary capstone experiences rather than just a single discipline capstone project.\cite{3-5} However, it can be difficult to implement these programs without college support.\cite{6} Studies have shown though that the multidisciplinary courses and teams have produced better design solutions\cite{7} and more prepared students in certain areas like identifying needs and seeing the big picture of the design process compared to those students completing single discipline projects.\cite{8-10}

At The Ohio State University, engineering students have options with respect to their senior capstone experience. The engineering disciplines offer one or more capstone projects and students also have an option of choosing a multidisciplinary capstone course sequence. The Multidisciplinary Capstone Program (MDC) at The Ohio State University is a 2 semester capstone experience that matches multidisciplinary student teams with an industry sponsor. The industry sponsored projects give the students real-world engineering project experiences. In addition to being paired with an industry sponsor, the student teams have a faculty advisor from the university. The learning objectives of the MDC program are primarily focused on the 2013-2014 ABET Criteria 3 (a-k).\cite{11}

Initial studies have examined former student, current student, and industry sponsor views of the capstone learning outcomes.\cite{12-14} Some interesting trends emerged from these previous studies. With the industry sponsors they indicated many things were important to an early engineer’s career except managing a project. All groups indicated that analyze and interpret data and design a system, component or process to meet a desired need was extremely important. The analysis of these various groups have provided many future improvements for the MDC program. However, one group of participants is missing from the previous studies, the faculty advisors.

This paper seeks to expand on that work and examine the following research questions that are focused on the faculty advisor perceptions of the multidisciplinary capstone program learning outcomes: \textit{How do faculty advisors perceive the student preparation levels coming into the multidisciplinary capstone program? Additionally, how do the advisors perceive the importance of these characteristics to completing the multidisciplinary capstone project and how much does the capstone program contribute to these learning outcomes?}

Methods

\textbf{MDC Program Description}
The university 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. The university 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 650 students and over 50 companies through the spring of 2015. Non-engineering students are involved through an engineering sciences minor program. This promotes discipline diversity in the program while giving students academic credit.

**Faculty Advisor Role in MDC Program**
The faculty advisor helps manage the team, provide support and advice, and assess the team’s performance. The faculty advisors come from a variety of backgrounds and disciplines. Additionally, they could be first-year engineering instructors or faculty in a discipline. The time commitment for the faculty advisor is 3-5 hours per week in a typical week and this includes weekly meetings with the student team and sponsor and reviewing and assessing project deliverables.

It is important for advisors to understand that this is a student project and they act as mentors or coaches. The advisors are not to become the lead designer but to encourage students to seek their own sources of knowledge and create their own solutions. Advisors are expected to attend and help organize visits to the sponsor’s facilities that involve the student team. The advisors are encouraged to mentor the students throughout the project duration to promote continual growth in both academic and professional skills. This is accomplished by giving summative and informative feedback on assignments and interactions with the sponsor. The advisor also holds students accountable for their responsibilities by meeting deadlines, reviewing assignments and producing quality work. The advisor leads efforts to improve team effectiveness thru fostering leadership good communication and interpersonal skills within the team. A complete and detailed list of expectations can be found in Appendix A.

**Survey Description**
The survey was distributed to 13 of the programs current and past faculty advisors. The survey focused on the ABET Criteria 3 (a-k) program objectives show in Table 1 and various lifelong learning skills shown in Table 2. The lifelong learning skills were adapted from lifelong learning characteristics defined by Candy et al.\(^\text{15}\) and Knapper and Cropley.\(^\text{16}\) The learning outcomes were asked three times:

1. Rate the following based on how well the students were PREPARED prior to starting MDC:
2. Rate the following based on the IMPORTANCE to completing MDC:
3. Rate the following based on the CONTRIBUTION of the MDC program to meet the following learning outcomes:

The lifelong learning characteristics were only asked once in the survey; to rate them based on the importance to a student’s academic and professional career.
### Table 1: Learning Outcomes of the MDC Program

<table>
<thead>
<tr>
<th>Learning Outcome/ABET Criteria</th>
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<tbody>
<tr>
<td>1 Design and Conduct Experiments</td>
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<tr>
<td>2 Analyze and Interpret Data</td>
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<tr>
<td>3 Design a system, component or process to meet a desired need with realistic constraints</td>
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<td>4 Function in a multidisciplinary team</td>
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<tr>
<td>5 Function in cultural and ethnically diverse environments</td>
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<tr>
<td>6 Manage an engineering project</td>
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<tr>
<td>7 Identify, formulate, and solve engineering problems</td>
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<tr>
<td>8 Communicate effectively orally: presentations, meetings, etc.</td>
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<tr>
<td>9 Communicate effectively in writing: Letters, technical reports, etc.</td>
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<tr>
<td>10 Use modern techniques, skills, and modern engineering tools</td>
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<tr>
<td>11 Use computing technology</td>
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<tr>
<td>12 Recognize the need for and engage in life-long learning</td>
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### Table 2: Survey Question Concerning Lifelong Learning Characteristics

<table>
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<tr>
<th>Lifelong Learning Characteristics</th>
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<tbody>
<tr>
<td>1 Relate academic learning to practical issues</td>
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<tr>
<td>2 Engage in self-direction and self-reflection in job performance</td>
</tr>
<tr>
<td>3 Locate information to complete engineering projects</td>
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<tr>
<td>4 Adapt learning/problem solving strategies to solve open-ended problems</td>
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<tr>
<td>5 Meet deadlines</td>
</tr>
<tr>
<td>6 Manage time in an effective manner</td>
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<tr>
<td>7 Take responsibility for seeking information</td>
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### Results and Discussion

**Advisor Survey Participants**

The survey was distributed to 13 former faculty advisors who had worked with the program during the period 2013-2015. Out of the 13 advisors, 11 completed the survey. While this sample size is small, in the history of the program there has only been approximately 20 faculty advisors. Many advisors stay with the program for multiple years, negating the need to recruit more and more faculty to work with the program. Therefore, the sample shown here demonstrates a large percentage of the recent faculty advisors in the program. As shown in Figure 1, the distribution of the faculty advisor survey participants highlights that less than half were advising for the first time and 6 had been advising for 2 or more years.
The advisors were also asked how much time they spent per week advising a single project. The results are shown in Figure 2, indicating that the time commitment for advisors is what is expected of them with a majority of respondents in the 2-5 hour range.

**Advisor Learning Outcome Results**

The examination of the advisor perceptions of the learning outcomes leads to a few ways to look at the data, which is shown in Figures 3-5. First, it allows us to see what the advisors think the student’s level of preparation is at the start of their capstone project. This is interesting since they each teach engineering students at various levels, from freshman up through seniors. Being a part of the preparation of these students gives them a unique way to evaluate their preparedness. Additionally, compared to students’ self-assessment, they may provide a more realistic perspective. Learning outcomes where students are reported to be least prepared...
include: “Manage an engineering project”, “Design and conduct experiments”, “Analyze and interpret data”, and “Life-long learning”. These outcomes could be shared with the engineering departments to see how students can be more prepared in these areas entering their senior year. When looking at the first three outcomes listed, it is clear that they are important to completing a capstone project and that the MDC program does manage to contribute to the growth of that learning outcome.

Looking at learning outcomes where not as much contribution occurs from the MDC program includes the area of “Use modern techniques, skills, and tools.” Based on how important faculty advisors feel this is to completing the capstone, and how low they rated the contribution of the MDC to growing in this learning outcome lends it to be an area for future improvement. The next two largest gaps between importance and contribution is in the outcomes of “Communicate effectively in writing” and “Use computing technology”. Again these two learning outcomes point to some possible improvements for the MDC program.

It is encouraging to note that for all other learning outcomes, the faculty advisors rate the contribution of the MDC program very high and close to its importance to completing the MDC project. Since these are learning outcomes of the program it is good that the faculty advisors see that the program does help contribute to these areas. Even outcomes with areas for improvement still report a relatively strong contribution by the MDC program. The outcome with the smallest contribution from the MDC program is “Life-long learning.”

![Figure 3: Learning Outcome Survey Responses (Extremely and Very Prepared, Extremely and Very Important, or Extremely and Very Helpful at Contributing to)](image-url)
Figure 4: Learning Outcome Survey Responses (Extremely and Very Prepared, Extremely and Very Important, or Extremely and Very Helpful at Contributing to)

Figure 5: Learning Outcome Survey Responses (Extremely and Very Prepared, Extremely and Very Important, or Extremely and Very Helpful at Contributing to)
Advisor Lifelong Learning Results
From the learning outcome survey, lifelong learning was tied for the lowest in preparation, lowest in importance to MDC, and lowest in contribution from MDC. However, when asking for lifelong learning characteristics that advisors thought were important to student’s academic and professional careers 4 out of 7 received 100% of responses ranking them as extremely important or very important as shown in Figure 6. The two lowest rated areas were “Relate academic learning to practical issues” and “Locate information to complete engineering projects”. These may indicate that there is an expectation that information may be provided to early career engineers by their employers and maybe relating the academic learning to practical issues is not as important early on compared to other areas.

Figure 6: Lifelong Learning Characteristics Survey Responses
(Extremely and Very Important)

Conclusions and Future Work
This study looked at the learning outcomes from a Multidisciplinary Engineering Design Capstone program from the viewpoint of the faculty advisors that advise the student teams. Based on the results from this survey it is clear that the faculty advisors value the program and think that it achieves in the growth of the students in most of the learning outcomes. However, the areas that have room for improvement within the MDC program include: “Use modern techniques, skills, and tools,” “Communicate effectively in writing,” and “Use computing technology”. Each of these three outcomes will be addressed below.
For the outcome “Use modern techniques, skills, and tools,” additional training could be provided for various tools that students may need to use to complete their projects. Students could also be exposed to the “state of the art” techniques, skills, and tools within the lecture of the MDC course. While these might not be used by all teams to complete their project, the exposure to them within the lecture would allow them to be aware of their existence and resources could be provided to give them more information and additional training if desired. These “state of the art” areas could be presented by the course instructors, faculty advisors, industry sponsors, or alumni of the program currently working in industry. A mix of presenters could provide additional perspectives and a wider range of information.

Technical writing is an area of concern throughout the entire engineering curriculum from first-year engineering up through capstone. It is not surprising that an area of improvement is to “Communicate effectively in writing.” However, the MDC program is positioned well within a department with a technical communication group and a first-year engineering program. These survey results point to clear collaborative efforts with both of these groups. Technical communication is taught in the first-year engineering program and then again for most students through a writing class taught by the technical communications faculty. Involving both of these groups in designing technical writing requirements, guidelines, and assessment tools would help elevate this area in the MDC program.

The final area of improvement, “Use computing technology,” could include increased access to computer labs and computer software. Many times students only have access to the computing technology of the department they belong to. While, IT support is localized within a department and multi-department agreement for MDC might be investigated to allow some of this cross-discipline use of computing technology. Additionally, training or training resources on modern computing software would help elevate the knowledge of the students both in completing their capstone project, and their knowledge for future employment.

It is clear through this survey that the faculty advisors play an important role in the MDC project and their perceptions indicate that the MDC program is very strong at achieving most of its learning outcomes. The areas of improvement here will help elevate the program. Additionally studies in the future could examine all stakeholders together to see where the various groups disagree with respect to preparation, contribution, and importance. This will help put all of the results into the context of the larger picture of the MDC program.

References
Appendix A

Capstone Project Advisor Role

Industry-sponsored projects require participation by multiple parties to ensure success. A commitment by the company to help ensure an effective student learning experience is fundamental. The Multidisciplinary Engineering Design Capstone staff select companies willing to assign an effective liaison to the team. Additionally, we assign a faculty advisor to each team to serve as coach. These advisors are typically faculty members with experience working with student teams and industry projects and with some degree of technical familiarity with the project scope. Faculty advisors typically invest 3-5 hours per week with the project team. Some guidelines and expectations for each project advisor are listed in more detail below. While these are guidelines, they include those tasks that generally lead to a successful team project.

1. Attend the kick-off meeting with the student team and sponsor organization.
   - Assist in defining a realistic project scope to avoid unrealistic expectations.
   - Lead the discussion to define realistic project goals.
   - Establish logistics for team visits, meetings, and presentations.

2. Advise the student team.
   - Help the team create a charter and assign roles (especially a team leader).
   - Coach the team leader, create a time-line (Gantt chart), define tasks, and assign responsibilities.
   - Attend and advise students in weekly status-review meetings.
   - Attend all customer conference calls, design reviews, and presentations.
   - At each weekly meeting, review past performance, future tasks, and hurdles. Assist when unnecessary hurdles arise that may detract from reaching the goals.
   - Encourage selection of a sponsor liaison and coach this person in professional communication.

3. Hold the student team accountable for their responsibilities.
   - Review notes and/or any unnecessary delays in meeting project deadlines.
   - Approve all project expenses and purchases of prototype parts.
   - Review and approve technical drawings and fabrication instructions.

4. Grade the team’s overall performance and evaluate individual contribution for:
   - Meeting the course learning objectives and expectations.
   - Implementing the design process and applying knowledge and skills to the project.
   - Personal commitment to achieve results and contribute to team effort.
   - Oral presentations, project notebooks, and written reports.
   - Quality of the final design and testing results.

5. Lead efforts to improve team effectiveness.
   - Administer formative assessments and use them to improve students’ contribution.
- Foster team building, leadership, and interpersonal skills within the team.
- Coach effective and professional communication with sponsor.

6. Encourage students to seek personal development as a result of formative assessments.
7. Promote consistent communication guidelines (written and oral).
8. Participate in summative and informative assessments (grading) based upon standard rubrics.

*Note: It is important for advisors to understand that this is a student project and that they act as coaches. It is important not to become the lead designer but to encourage students to seek their own sources of knowledge and create their own solutions.*