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Infusing an Entrepreneurial Mindset into Multidisciplinary Capstone Curriculum: Learning Objectives, ABET Alignment, and Supporting Activities

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In a Multidisciplinary Capstone course, faculty have been integrating the entrepreneurial mindset into the programs learning objectives. The capstone course focuses on real-world industry sponsored projects that students work on over a two-semester sequence. This paper describes the capstone course as well as the entrepreneurial mindset learning objectives that have been developed and incorporated into the course. These learning objectives are presented as well as their alignment to the ABET Criterion 3 (1-7). Curriculum changes and activities to align with the new learning objectives are presented as well as lessons learned from the faculty. This is the first step in a larger study that will look at student and sponsor perceptions of the entrepreneurial mindset learning objectives and ABET criteria.

Keywords: Multidisciplinary, ABET, Entrepreneurial Mindset

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Introduction

Wanting to develop the mindset of engineering students to think beyond their technical knowledge into how their work as engineers impacts the world is an important part to a comprehensive engineering curriculum. Part of this mindset can be thought of as the entrepreneurial mindset where students are encouraged to identify opportunities to create value, be curious about the world around them, and connect ideas and topics together to form unique solutions. This Entrepreneurial Mindset (EM) has been a focus of many schools within the Kern Entrepreneurial Engineering Network (KEEN) and has been guided by a general EM framework[1]. This entrepreneurial mindset is something that can be developed[2]. At The Ohio State University, faculty have been infusing EM into courses at the first-year3,4,5 and capstone level[6] since 2017. These curriculum changes have been guided by identifying learning objectives that align with EM and then associating activities to help support those learning objectives along with appropriate assessments. This paper highlights the curriculum changes and learning objectives in a multidisciplinary capstone course to infuse and strengthen the EM content in the course.

Course Context

The Multidisciplinary Design Capstone (MDC) program at The Ohio State University is an optional capstone experience available to all engineering disciplines. This 2-course sequence pairs student teams up with industry sponsors to work on a real-world industry driven project. All of Ohio State's 14 engineering disciplines have participated across the lifetime of the program (since 2009). Students who enroll, elect to take this course instead of the senior capstone project in their discipline. Beyond engineering students, this course also includes non-engineering students through the Engineering Science Minor program. These non-engineering students have completed first-year engineering and must participate in an engineering capstone course in addition to ~5 additional credits of engineering courses to receive the minor. Many of these engineering science minor students are students who originally intended to get an engineering degree but transferred out of the college to another major like math, psychology, or business. The truly multidisciplinary nature of these teams beyond just engineering disciplines adds to the richness and value that these project teams are able to provide the industry sponsors. While many of the elements of EM were already a natural part of the course, the infusion of EM and strengthening of components that already existed was a goal of the program. In order to do this, it was important to establish specific learning objectives related to EM.

Entrepreneurial Mindset Learning Objectives

In order to create learning objectives that align with EM, a backwards design[7] approach was taken to establish a set of objectives. While other ways of

operationalizing EM exist[8, 9], it was important for the faculty at Ohio State to be involved in the development of these objectives using the others' definitions as a guide. These objectives were modified and critiqued by stakeholders[10, 11] until a final set of 14 EM Learning Objectives (EMLOs) were established. The final EMLOs are found in Table 1. Each EMLO was given three levels of potential achievement which were meant to aid in potential scaffolding of the curriculum. The beginning level was focused on introducing the students to the concept, the intermediate level was focused on using the concept to apply to a problem, and the advanced level was meant to be as close to a real-world project-based application of the EMLO as possible in a classroom context. As such it is expected that in a first-year course many of the EMLOs would be met at the beginning and intermediate level, but in a senior capstone level course these would be met at the advanced level. An example of the 3 levels is given below for the EMLO "Develop Concepts and Visual Representations".

- Develop Concepts and Visual Representations: Represent and refine conceptual solutions through the use of visual representations.
    - (Advanced) Develop a detailed representation of a conceptual solution.
    - (Intermediate) Illustrate preliminary conceptual solutions through visual representations.
    - (Beginner) Explain the value of modeling conceptual solutions through visual representations.

Alignment with ABET

As the senior capstone course is the culminating experience for all disciplines, it is an important part of ABET assessment. Since assessment is always ongoing for ABET, alignment with EM was a logical step to take. As these EMLOs were developed the course designers considered how they aligned with existing ABET criteria. ABET criterion 3: Student Outcomes 1-7 are given below.

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. an ability to communicate effectively with a range of audiences.
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

The course designers and EMLO developers worked together to create a relationship between the EMLOs and ABET criterion 3. These relationships were based on the definitions of the EMLOs compared to the ABET criterion student outcomes. The group identified key common terms or concepts between the two to identify correlations. Table 1 shows the established alignment between the EMLO and ABET criteria. Any EMLO that was considered to be meeting the ABET criteria at its advanced EMLO level is shown with an X in the appropriate box. A limitation to this alignment that there may be some variation in how EMLOs are met in various projects and therefore the alignment may not always be 1-1 for all EMLO activities. However, these represent the ideal alignment for advanced EMLO activities in a capstone course. As shown by Table 1, the EMLOs meet several of the ABET criteria which allow for the course developers to create assignments that meet multiple learning outcomes.

Table 1: EMLO and ABET Criteria Alignment

	ABET Criterion 3						
EMLO	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1. Demonstrate Curiosity	X		X		X		X
2. Analyze Accepted Solutions	X	X				X	X
3. Integrate Information through Making Connections	X	X		X		X	X
4. Evaluate Social, Economic, and Environmental Risks and Benefits		X		X		X	
5. Identify Opportunity to Create value	X	X		X			X
6. Learn from Failure				X	X		X
7. Define Problem	X	X	X		X		
8. Define User Needs		X	X		X		X
9. Develop Concepts and Visual Representations	X		X				
10. Analyze Solutions and Develop Design Requirements	X	X				X	
11. Perform Detailed Design	X	X					
12. Test and Validate Solutions		X				X	
13. Identify and Utilize Resources and Expertise	X			X	X		X
14. Consider How to Protect Intellectual Property				X			X

Curriculum to Support EMLOs and ABET

The original capstone course included major deliverables such as written design reports, oral presentations, and progress status reports. After establishing which EMLO criteria were going to be addressed in the MDC courses, activities were developed to help support and assess the development of these learning objectives. Below are 3 examples of activities that were included in the course to support

these EM objectives. Students completed these activities in class as a team to help them scaffold their work towards their major capstone project milestones.
The first example is a user needs and market analysis assignment. This assignment aligns with EMLO 8 "Define User Needs" and EMLO 5 "Identify Opportunity to Create Value". This activity is helpful in students being reflective about users as well as the current market space. As these projects are scoped and identified by the industry sponsors, it is important for the student teams to still consider the users and market for the project to develop an impactful solution even if the industry sponsors already considered that in the project scoping.

Activity Title: *User Needs, Status Quo and Markets*
Prompts:
1. Define the User Needs for your project:
   a) Who is your user or users?
   b) What are their top 3-5 needs?
2. Define the Status Quo and the Primary Market for your project:
   a) What is currently being done (or not done)?
   b) What are the pros and cons of the status quo?
   c) Who could potentially be affected by changes in the status quo? i.e. Who is the primary and secondary markets?

Figure 1: Activity 1- User Needs, Status Quo and Markets

The next activity is a value proposition statement. This activity aligns with EMLO 5 "Identify Opportunity to Create Value". Again, this is a crucial step in the Entrepreneurial Mindset and an important component to creating an impact.

Activity Title: *Value Proposition*
Prompts:
Submit your first version of a value proposition. Start with these 3 key items:
1. Identify a specific problem being dealt with by a specific audience.
2. Articulate how the product/service being sold solves this specific problem.
3. Communicate the audience-specific intangible and quantifiable benefits of the solution

Then, work to refine and simplify into a phrase.

Figure 2: Activity 2- Value Proposition

This last activity is about considering the design requirements which aligns with EMLO 10 "Analyze Solutions and Develop Design Requirements".

Activity Title: *Design Requirements*
Prompts:
1. Work with your team to review your User Needs.
2. Build a table in Excel with a column for User Needs and associated columns for all Design Requirement details.

Figure 3: Activity 3- Design Requirements

These activities were incorporated into the major project deliverables. For example, the first activity was included as a section of the major deliverable, Problem Identification. EMLO 8 was used as part of the rubric to assess the student deliverable.

From implementing these activities, the MDC instructors observed that students felt that these activities were just busy work or non-relevant to the project. They struggled with making the connection between the activity and the project progression. The instructors have adjusted the activities by clearly stating the connection between the activity, learning outcomes and project progress. Another observation included the development of student's perceptions of the EMLOs. At the beginning of the course sequence, students saw the EMLOs as just another set of learning outcomes that instructors included in the syllabus. By the end of the course sequence, the students expressed a better understanding of what the EMLOs meant, and their purpose related to their project success. To help identify the impact on student learning of these three EMLOs (number 5, 8 and 10), students were given a survey at the beginning and end of project for students to self-identify their perceptions of preparedness for each of the EMLOs (Likert scale 1 to 5, with 1 - not prepared at all, 2 – minimally prepared, 3 – somewhat prepared, 4 – adequately prepared, to 5 - very prepared. From Figure 4, the authors observed an improvement in the student's perception of preparedness in all three EMLOs from the beginning of the project to the end. In addition, the project sponsors and faculty advisors were given the same survey at the end of the project to compare their perceptions of student's preparedness as well. The student and sponsor/advisor showed similar results for these EMLOs at the end of the project (See Figure 4).

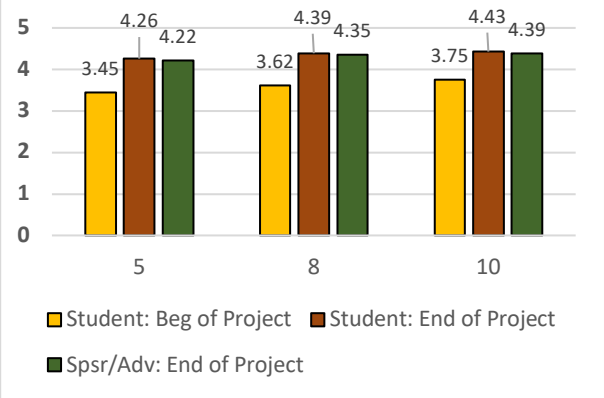

Figure 4: EMLO 5, 8, 10 Perceptions of Preparedness

Future Work & Conclusions

This paper highlighted curriculum changes that were made to a multidisciplinary capstone course to support EM development in senior engineering students. These EM learning objectives were aligned with ABET and adding into the course through course activities along with the general project deliverables. Over the past 2 years the course has collected student feedback on the EMLOs and ABET criteria as well as feedback from the

industry sponsors and faculty advisors. These various stakeholder perceptions of the integration of EMLOs are needed for the continuous improvement of the course. The next step will be for an analysis of these surveys to ensure alignment of the EMLOs across all the diverse real-world student projects.

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References

[1] "The KEEN Framework | Engineering Unleashed." Accessed: Jan. 15, 2024. [Online]. Available: https://engineeringunleashed.com/framework

[2] E. Gottlieb, J. A. Ross, and J. Simon, "Made, Not Born: HBS Courses and Entrepreneurial Management - Alumni - Harvard Business School." Accessed: Jan. 15, 2024. [Online]. Available: https://www.alumni.hbs.edu/stories/Pages/story-bulletin.aspx?num=6132

[3] D. M. Grzybowski, X. Tang, E. Park, A. Leonard, J. DeLano, and K. Zhao, "Integration of Entrepreneurial-minded Learning," *ASEE Annual Conference and Exposition, Conference Proceedings*, vol. 2020-June, Jun. 2020, doi: 10.18260/1-2--34852.

[4] R. Desing, K. M. Kecskemety, R. L. Kajfez, D. M. Grzybowski, and M. F. Cox, "A Multi-institution Investigation into Faculty Approaches for Incorporating the Entrepreneurial Mind-set in First-year Engineering Classrooms," *ASEE Annual Conference and Exposition, Conference Proceedings*, Jun. 2019, doi: 10.18260/1-2--31972.

[5] R. M. Desing, R. L. Kajfez, K. M. Kecskemety, and D. M. Grzybowski, "Intersections Between Entrepreneurial Minded Learning, Identity, and Motivation in Engineering*," *International Journal of Engineering Education*, vol. 38, no. 5(A), pp. 1389–1407, 2022, Accessed: Apr. 24, 2023. [Online]. Available: https://www.ijee.ie/1atestissues/Vol38-5A/16_ijee4263.pdf

[6] K. M. Kecskemety and B. B. Rhoads, "Integration of EML Curriculum Changes - From First-Year to Capstone," in *AIAA AVIATION 2023 Forum*, in AIAA AVIATION Forum. , American Institute of Aeronautics and Astronautics, 2023. doi: doi:10.2514/6.2023-3659.

[7] G. P. Wiggins, J. McTighe, and Hawker Brownlow Education, *Understanding by design*. Hawker Brownlow Education, 2005.

[8] J. S. London, J. M. Bekki, S. R. Brunhaver, A. R. Carberry, and A. F. Mckenna, "A framework for entrepreneurial mindsets and behaviors in undergraduate engineering students: Operationalizing the Kern family foundation's '3Cs,'" *Adv Eng Educ*, vol. 7, no. 1, pp. 1–12, 2018.

[9] J. B. Hylton, D. Mikesell, J.-D. Yoder, and H. LeBlanc, "Working to Instill the Entrepreneurial Mindset Across the Curriculum," *Entrepreneurship Education and Pedagogy*, vol. 3, no. 1, pp. 86–106, 2020, doi: 10.1177/2515127419870266.

[10] K. M. Kecskemety, L. Rumreich, B. Rhoads, F. Logan, J. T. Allenstein, and N. Sattele, "Work-in-Progress: The Entrepreneurial Mindset in Industry Sponsored Capstone Projects: Balancing Project Needs and Learning Objectives," *2023 IEEE Frontiers in Education Conference (FIE)*, pp. 1–5, Oct. 2023, doi: 10.1109/FIE58773.2023.10343507.

[11] L. E. Rumreich, F. Logan, Z. Dix, N. R. Sattele, K. M. Kecskemety, and A. D. Christy, "Comparison of Entrepreneurial Mindset Course Learning Objectives: Evaluating Consistency and Clarity," *ASEE Annual Conference and Exposition, Conference Proceedings*, vol. 2020-June, Jun. 2020, doi: 10.18260/1-2--34312.