Work-In-Progress: Using Technical and Professional Communication Assignments to foster Entrepreneurial Mindset in a Multidisciplinary Design Capstone Course

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Introduction

The Kern Entrepreneurial Engineering Network (KEEN) focus on partnering with more than 60 educational institutions to foster an entrepreneurial mindset (EM) in engineering students has resulted in meaningful impacts to engineering education, faculty professional development, and curriculum [1]. This EM approach to curriculum is one tool for supporting the development of sociotechnical engineers—preparing students to solve global engineering problems utilizing the KEEN EM framework's 3Cs: curiosity, connections and creating value. When coupled with engineering thought and action, EM is expressed through collaboration and communication and founded on character. The sociotechnical engineer uses both technical and non-technical (e.g. collaboration and communication) skills in order to work effectively. The engineering capstone course, as a culminating experience for students preparing to embark on their professional careers, serves as an ideal site to further train students to to transfertechnical knowledge gained from prior coursework to new experiences, build and strengthen their socio- and technical skills, and to approach their capstone projects utilizing the EM framework. This work in progress paper will describe the process and impact of integrating EM into a multidisciplinary capstone two-semester course sequence through the use of writing instruction and assignments. The intervention positions the course—and its technical and professional communication-specific lectures and assignments—as a site for instructors and students alike to be what Rebecca Nowacek terms "agents of integration" [2]. For instructors, this is demonstrated in the facilitation of transfer by creating an environment that encourages students to make connections between different areas of learning. For students, this integration is in how they adapt their prior technical knowledge, acquire new knowledge, and utilize professional skills to to demonstrate their learning through a team-based design project that requires evidenced-based iteration and justification of engineering decisions to be documented in a range of professional genres and audiences (meeting minutes, design reports, memos, emails, and presentations).

Background

The partnership between KEEN and The Ohio State University, began in 2017. Faculty across the College of Engineering, including the first-year engineering sequence and many capstone courses, have successfully integrated EM into their course curriculum. As a result of the initial integration of EM outcomes into first year engineering curriculum, assessment found that the inclusion of EM learning outcomes increased student performance and this led to the expansion of entrepreneurial minded learning (EML) into honors curriculum, capstone courses, and into Professional Learning Communities to support faculty [3].

The Multidisciplinary Design Capstone (MDC) program at Ohio State offers an opportunity for both engineering and non-engineering senior students to work together on industry sponsored projects in a design process-focused two semester course sequence. Changes to the course began with the 2020-2021 academic year, with the addition of a technical communications faculty member to the teaching team. While the course already emphasized interdisciplinarity by forming student teams with a variety of engineering and non-engineering backgrounds, this shift to team teaching further modeled that interdisciplinarity with the integration of writing instruction and practice within broader engineering disciplinary contexts. The program director and technical communications faculty member have worked together as the core instructional team for the course, with the support of additional faculty (teaching, advising) and graduate student teaching assistants. The initial year of this collaboration involved the technical communications faculty reviewing existing course materials and lectures and making initial revisions to the course assignments and rubrics to align with desired technical and writing outcomes. This iteration and revision practice has continued throughout the teaching model. The ultimate objective of this collaboration is to emphasize capstone as a site of situated learning in the development of sociotechnical engineers with practice in recontextualizing—or making connections to use the EM framework—their technical and professional skills more readily to new contexts as they graduate from their undergraduate careers and enter the workforce [2],[4].

Beginning with the 2021-2022 academic year, MDC began revising the course to include EML outcomes in the course. Like the changes made starting in the previous academic year, this also included modifications to course activities, assignments, and lectures with a focus on the KEEN 3Cs: Curiosity, Connections, and Creating Value.

As curricular changes have been made, the faculty noticed a natural synergy between the goals of teaching students to use a rhetorical approach in their communication tasks and the 3Cs framework, especially Connections and Creating Value. More specifically, when we ask students to work in multidisciplinary teams on complex projects and communicate their work in a variety of genres (meeting minutes, status memos, class activities, design reports, and presentations) to a range of audiences (project advisors, sponsor employees, instructors) we are asking them to:

- Bridge gaps between technical experts and non-experts,
- Facilitate collaboration and knowledge sharing across disciplines, and
- Consider the importance of clarity in communicating technical information.

Practicing these skills as part of their senior capstone coursework serves the purpose of helping them connect their academic preparedness and technical knowledge to the professional skills that will help make them successful in their engineering careers. This creates value both for the student and the engineering workforce.

Effective communication ensures that technical solutions are understood and appreciated by stakeholders, demonstrates the practical benefits and relevance of technical work, and encourages feedback and continuous improvement based on user input. Rebecca Nowacek's perspective on teaching students to be agents of integration [2] emphasizes developing the ability to see and articulate connections across different contexts and disciplines and understanding the transfer of knowledge as a rhetorical act involving recontextualization. The writing process (prewriting/brainstorming, researching, drafting, revising/editing) serves as a tool for integration by helping students identify connections between different concepts and disciplines, articulate their understanding clearly to enhance communication and knowledge transfer, and adapt knowledge to new contexts through tailored communication for various audiences and purposes. An example of this is seen in the problem identification structure of the course. Student teams are familiarized with their project and asked to engage in activities and communication-focused assignments to research and develop an understanding of the problem, its stakeholders, and the market. Students collaboratively develop a problem statement and build a presentation around these tasks to deliver during class. Students receive feedback on their presentation design and delivery from their classmates and the instructional team. That feedback is then used as part of their development of the problem identification chapter of their design report. Aligning these concepts with KEEN's 3Cs, both KEEN's "Connections" and Nowacek's ideas emphasize drawing parallels between existing knowledge and new challenges. Writing assignments help students integrate information from different disciplines, fostering a holistic understanding, while effective communication bridges gaps between technical and non-technical audiences, enhancing collaboration and knowledge sharing. KEEN's "Creating Value" aligns with Nowacek's focus on demonstrating the practical benefits and relevance of technical work. At the same time, writing and communication-based activities and assignments help students articulate the focus of their project and, later, how their solutions address specific pain points and improve processes. By encouraging feedback and continuous improvement, students learn to adapt their work based on user input, ensuring ongoing value creation. This holistic approach not only prepares students for their engineering careers but also enhances their ability to contribute meaningfully to the workforce.

The MDC co-instructors' goals in integrating technical/professional communications into the course and emphasizing those skills inherent to the KEEN 3Cs have been to:

1. Provide opportunities for students to collaborate with a diverse and multidisciplinary group with different backgrounds.
2. Create a course where students can develop a broader perspective on problem-solving and innovation.
3. Enhance students' abilities to make connections between background knowledge, new knowledge, and to integrate diverse knowledge and skillsets.
4. Emphasize the need to adapt communication styles for various audiences while giving students opportunities to improve through the writing process: draft, revise, and provide feedback to peers, and utilize feedback from their peers and instructional team to make improvements.
5. Practicing the integration of technical and non-technical information.

Technical Communication Curriculum Alignment with EML

During the 2021-22 and 2022-23 academic years, the MDC instructional team revised previous assignments to improve communication curriculum outcomes based on student surveys and instructor observations of student work. The MDC instructional team aligned revised and new assignments to the Entrepreneurial Minded Learning Outcomes (EMLOs) that were developed by a KEEN sponsored grant [5]. These assignments included a combination of in-class activities, written assignments and presentations. All student work in the course has been mapped in a curricular crosswalk to ensure alignment with the course learning outcomes, the KEEN EMLOs, and ABET learning outcomes. An example of the curricular mapping of the aforementioned problem-focused activities and assignments is demonstrated in Table 1. Table 2 demonstrates how all assignments in the course have been aligned with the EMLOs. The major written deliverable included a report that included four chapters (Ch. 1 Problem Identification, Ch. 2 Systems Design, Ch. 3 Detail Design, Ch. 4 Final Design). The chapters were assigned throughout the 2-semester course with the previous revised chapter(s) being submitted with the current chapter (e.g. Ch. 1 & 2 would be resubmitted with revisions along with Ch. 3 submission).

Table 1: Curricular Crosswalk for Problem-Focused Activities and Assignments

			Course LOs					**KEEN EMLOs**						
WK	**SEM**	**Activities/Assignments**	**1**	**4**	**5**	**6**	**9**	**1**	**3**	**4**	**5**	**6**	**7**	**8**
3	AU	Class Activity 1: Writing for Audiences						X	X					
4	AU	Class Activity 2: Define User Needs				X		X	X	X				X
4	AU	Class Activity 3: Status Quo & Market Research				X		X	X	X			X	
5	AU	Presentation: Problem Identification	X	X	X	X		X	X	X	X		X	X
6	AU	Design Report Chapter 1 (Problem Identification)		X	X	X	X	X	X		X		X	X
11	AU	Design Report Chapter 1 (Problem Identification) Revision										X		

Table 2: EMLOs and Technical Communication Assignments

Entrepreneurial Minded Learning Outcome (EMLO)	**EMLO Definition**	**Related Tech. Comm. Assignments**
EMLO 1: Demonstrate Curiosity	Ask and encourage questions that facilitate and inspire growth and learning.	• Writing for All Audiences • Status Quo & market research • Problem identification presentation

		• Problem identification report (Ch. 1)
EMLO 2: Analyze Accepted Solutions	Explore a contrarian view of currently accepted products, processes, and services.	• Systems design report (Ch. 2) • Preliminary design presentation
EMLO 3: Integrate Information through Making Connections	Make connections between different domains of knowledge to reach new and innovative ideas and solutions.	• Systems design report (Ch. 2) • Preliminary design presentation • Detailed design report (Ch. 3) • Critical design presentation • Final design report (Ch. 1-4) • Final design presentation
EMLO 4: Evaluate Social, Economic, and Environmental Risks and Benefits	Evaluate social, economic, and environmental factors when considering ideas and solutions to problems.	• Final design report (Ch. 1-4) • Final design presentation
EMLO 5: Identify Opportunity to Create value	Create ideas for new products, processes, or services that provide a potential social, economic, or environmental value.	• Value proposition • Problem Identification report/presentation • Final design report (Ch. 1-4) • Final design presentation
EMLO 6: Learn from Failure	Persist through and learn from failure.	• Identify risks & contingency plans
EMLO 7: Define Problem	Based upon an identified opportunity, stakeholder feedback, primary research, and secondary research, create a formal definition of a specific problem.	• Problem Identification report (Ch. 1) • Problem identification presentation
EMLO 8: Define User Needs	Develop a list of needs from research and stakeholder(s) that support project objectives.	• Define user needs • Problem identification report (Ch. 1) • Problem identification presentation
EMLO 9: Develop Concepts and Visual Representations	Represent and refine conceptual solutions through the use of visual representations.	• Systems design report (Ch. 2) • Preliminary design presentation

EMLO 10: Analyze Solutions and Develop Design Requirements	Select a final concept solution based on user needs and develop design requirements.	• Systems design report (Ch. 2) • Preliminary design presentation • Detailed design report (Ch. 3) • Critical design presentation • Status Memo – Validation Plan • Assessment meeting presentation • Final design report (Ch. 1-4) • Final design presentation
EMLO 11: Perform Detailed Design	Perform detailed design driven by the set of design requirements and taking into account usability.	• Detailed design report (Ch. 3) • Critical design presentation • Final design report (Ch. 1-4) • Final design presentation
EMLO 12: Test and Validate Solutions	Develop a process to verify the solution meets the design requirements and validate results.	• Status Memo – Validation Plan • Assessment meeting presentation • Final design report (Ch. 1-4) • Final design presentation
EMLO 13: Identify and Utilize Resources and Expertise	Identify gaps in knowledge, resources that could fill that gap, and how those resources can be used to advance a solution.	• Team charter • Detailed design report (Ch. 3) • Critical design presentation • Status Memo – Prototype Plan • Assessment Meeting – Prototype Plan • Final design report (Ch. 1-4) • Final design presentation

EMLO 14: Consider How to Protect Intellectual Property	Recommend ways in which you can protect your own intellectual property and appropriately use other's intellectual property.	• Protecting your intellectual property within your project

Survey Results and Discussion

A technical communication survey was given to multidisciplinary capstone students at the beginning of autumn semester and at the end of spring semester of the two-semester course sequence starting in 2020-21 academic year and continuing through 2023-24 academic year. The survey questions asked the students to respond to their preparedness in communication and collaboration criteria at that point in time. The survey also collected various demographic data as well as their respective majors. The course included both engineering majors from different disciplines as well as non-engineering majors who were completing an engineering science minor. For this work in progress paper, the MDC instructional team reviewed and analyzed the responses as an aggregate group without examining the demographic differences. As this is a first-step in a larger study, future analysis will include the demographic data as well as comparing responses from engineering majors and non-engineering majors. The 2020-21 technical communication survey results served as baseline data for the revisions to curriculum. The data from the 2023-24 academic year was used to evaluate the impacts of the communication related lectures and assignments as they were fully implemented into the course at this time. For this paper, the MDC instructional team compared data from the 2020-21 academic year to the 2023-24 academic year. An EMLO student survey was initiated in the 2021-22 academic year and continued through the 2023-24 academic year. These EMLO survey results were used to help provide context and comparisons to the technical communication surveys.

The technical communication survey respondents were asked to rate their level of preparedness based on a 5-point Likert Scale (1 – Not Prepared, 2 – Minimally Prepared, 3 – Somewhat Prepared, 4 – Adequately Prepared, 5 – Very Prepared) in eight categories. In addition to these eight categories, the end of spring semester survey included an additional 5 categories that focused on communication within a professional work environment.

A Mann-Whitney U-Test for non-parametric data was performed comparing the beginning of autumn and end of spring data for both 2020-21 and 2023-24 academic years for each survey item in the Technical Communication Survey. The 2020-21 results are shown in Table 3. Every category showed an increase in the average Likert value, however only four of the eight category comparisons were statistically significant differences ($p<0.05$).

Table 3: 2020-21 Technical Communication Survey Results

Please rate your current level of preparedness in the following categories:	**Beg. (n=41)**	**End (n=47)**	**End - Beg**	**p-value**
overall writing skills needed for job performance.	3.95	4.28	0.33	0.051
communication skills relevant to engineering.	4.02	4.15	0.12	0.514
interpreting data and communicating about its meaning.	3.93	4.32	0.39	0.014**
ability to communicate for many purposes.	4.02	4.36	0.34	0.033**
ability to re-purpose communications in a variety of forms.	3.73	4.28	0.54	<0.001**
ability to edit your own writing.	3.76	4.15	0.39	0.054
ability to write collaboratively with a diverse group of people.	4.00	4.17	0.17	0.463
ability to collaboratively edit the writing of your peers.	3.78	4.32	0.54	0.006**

NOTE: ** indicates statistically significant differences (<0.05).

The 2023-24 results are shown in Table 4. Every category showed an increase in the average Likert value and all eight categories had statistically significant differences ($p<0.05$). Therefore, students indicated that they were more prepared at the end of the multidisciplinary capstone course sequence than at the beginning.

Table 4: 2023-24 Technical Communication Survey Results

Please rate your current level of preparedness in the following categories:	**Beg. (n=59)**	**End (n=45)**	**End - Beg**	**p-value**
overall writing skills needed for job performance.	3.80	4.42	0.63	<0.001**
communication skills relevant to engineering.	3.56	4.22	0.66	<0.001**
interpreting data and communicating about its meaning.	3.73	4.27	0.54	<0.001**
ability to communicate for many purposes.	3.73	4.40	0.67	<0.001**
ability to re-purpose communications in a variety of forms.	3.44	4.33	0.89	<0.001**
ability to edit your own writing.	3.73	4.42	0.69	<0.001**
ability to write collaboratively with a diverse group of people.	3.64	4.29	0.64	<0.001**

ability to collaboratively edit the writing of your peers.	3.58	4.27	0.69	<0.001**

NOTE: ** indicates statistically significant differences (<0.05).

When comparing the 2020-21 (baseline) results to the 2023-24 results in Table 5, there was an increase in the level of preparedness for each of the categories.

Table 5: 2023-24 Technical Communication Survey Results

Please rate your current level of preparedness in the following categories:	**2020-21 End - Beg**	**2023-24 End - Beg**	**End – Beg Difference (23/24 – 20/21)**
overall writing skills needed for job performance.	0.33	0.63	0.30
communication skills relevant to engineering.	0.12	0.66	0.54
interpreting data and communicating about its meaning.	0.39	0.54	0.15
ability to communicate for many purposes.	0.34	0.67	0.33
ability to re-purpose communications in a variety of forms.	0.54	0.89	0.35
ability to edit your own writing.	0.39	0.69	0.30
ability to write collaboratively with a diverse group of people.	0.17	0.64	0.47
ability to collaboratively edit the writing of your peers.	0.54	0.69	0.15

An EMLO student survey was initiated in the 2021-22 academic and continued through the 2023-24 academic year. The EMLO survey respondents were asked to rate their level of preparedness based on a 5-point Likert Scale (1 – Not Prepared At All, 2 – Minimally Prepared, 3 – Somewhat Prepared, 4 – Adequately Prepared, 5 – Very Prepared) in 14 EMLOs.

A Mann-Whitney U-Test nonparametric test was performed comparing the beginning of autumn and end of spring data. The results are shown in Table 5. The results show that all 14 EMLO comparisons resulted in a statistically significant increase in Likert values from beginning to end. Therefore, students indicated that they were more prepared at the end of the multidisciplinary capstone course sequence than at the beginning.

Table 6: 2023-24 EMLO Survey Results

Entrepreneurial Minded Learning Outcome (EMLO)	Beg. (n=)	End (n=)	End – Beg.	p-value
EMLO 1: Demonstrate Curiosity	3.82	4.33	0.51	<0.001**
EMLO 2: Analyze Accepted Solutions	3.42	4.30	0.88	<0.001**
EMLO 3: Integrate Information through Making Connections	3.38	4.26	0.88	<0.001**
EMLO 4: Evaluate Social, Economic, and Environmental Risks and Benefits	2.91	3.96	1.05	<0.001**
EMLO 5: Identify Opportunity to Create value	3.31	4.29	0.97	<0.001**
EMLO 6: Learn from Failure	3.86	4.36	0.50	<0.001**
EMLO 7: Define Problem	3.32	4.24	0.92	<0.001**
EMLO 8: Define User Needs	3.43	4.29	0.86	<0.001**
EMLO 9: Develop Concepts and Visual Representations	3.39	4.26	0.87	<0.001**
EMLO 10: Analyze Solutions and Develop Design Requirements	3.34	4.30	0.96	<0.001**
EMLO 11: Perform Detailed Design	3.17	4.20	1.03	<0.001**
EMLO 12: Test and Validate Solutions	3.12	4.10	0.98	<0.001**
EMLO 13: Identify and Utilize Resources and Expertise	3.29	4.17	0.89	<0.001**
EMLO 14: Consider How to Protect Intellectual Property	2.90	4.09	1.19	<0.001**

NOTE: ****** indicates statistically significant differences (<0.05).

Conclusions and Future Work

From the results of student perceptions, the inclusion of a technical communication co-instructor in addition to the curriculum revisions has had an increase in student self-efficacy on technical communication skill preparedness. This increased focus on technical communication skills has been aligned with an increased focus on EMLOs. Since many of the EMLOs were introduced and assessed through various writing assignments and activities, it is natural that these skills are connected to the increase in student self-perceptions.

As this is the beginning of a larger study looking into the impact of this technical communication focus in an MDC course, future work will examine differences in self-perceptions of various demographic groups specifically gender and minoritized populations. One of the other key groups that the instructional team wants to explore is the different self-perceptions of engineering students compared to the students who are majors in non-engineering fields but obtaining a minor in engineering science. These students may have different formal communication backgrounds with many coming from Arts and Sciences or Business fields that may result in different experiences as they learn about and practice technical communication. Related to this the instructional team is also interested in exploring the impact of prior technical communication experiences including courses, experiential learning, and professional experiences. Finally, while student self-reported perceptions can be useful in generating insights into the curriculum impacts, direct assessment of student work from before and after the implementation of these curricular and pedagogical changes will provide a more robust study in the future. These results will hopefully support and encourage other engineering faculty to engage with technical communication faculty to make similar improvements throughout the undergraduate engineering curriculum.

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