

## **Design of a Unique Industry-Oriented Project-Based Capstone Course for Engineering Technical Managers**

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### **Abstract**

This work in progress (WIP) paper aims at demonstrating the innovative design of integrating a communication course with the Capstone course, which is part of the Master of Engineering Technical Management (METM), a 21-month online graduate program for working professionals in the engineering technical management fields. As the culmination of their graduate study, students must identify an organizational/technical challenge, formulate a feasible project plan to address the issue to bring impact to the organization. During this process, they will conduct research, create a strong business case for their industry sponsors (stakeholders), collect and analyze data, and make strategic decisions with the knowledge and skills learned throughout the program. The themes of the Capstone projects cover a broad spectrum of the Engineering Management Body of Knowledge (EMBOK), for example, Leadership and Organizational Management, Project Management, Strategic Planning and Management, Financial Resource Management, etc., topics include process improvement and optimization, cost reduction, market research for new product/technology, organizational culture and employee engagement, etc. Due to the nature of this course, the industry sponsors play a critical role at the very beginning, from project buy-in, resources allocation, approval of process (interviews, surveys, implementation of the recommendations), etc., that all require students to propose ideas, report progress, and keep the project flow on track effectively and efficiently.

What is unique about this course is the integration of an auxiliary course named “*Persuasive Communications for Technical Managers*” (or “Communications”), which goes hand-in-hand with the Capstone course; it coaches students on indispensable communication skills using interactive scenario-based simulations of real-time workplace conversations with upper management and direct reports, as well as providing guidelines on oral and written communications techniques.

This Capstone course utilizes a project-based learning approach and the Communications course as a supplementary tool. As an outcome, students not only get to apply relevant technical knowledge and leadership skills to real-world problem-solving processes, but also have the opportunity to demonstrate their ability to lead and execute fruitful changes in their organizations. It is a perfect testament to impactful academic-industry collaboration. Both qualitative and quantitative data will be collected, including course and program evaluation surveys, student reflections, to gauge the perception of learning outcomes and course

effectiveness. Other institutions could use this course as a design template when offering similar project-based courses.

*Keywords: Project-based learning, academic-industry collaboration, Capstone project, course design, Working Professionals*

## **Background- Program Introduction**

### **Workplace during the Time of Uncertainty**

The Covid-19 pandemic has impacted almost every aspect of our lives: teachers learned to teach elementary school subjects using Zoom or Microsoft Teams (web conferencing tools) while managing chaotic bathroom and snack breaks; online grocery shopping now delivers fresh produce to your door along with your favorite ice cream and toilet papers in as fast as two hours; virtual online visits to clothes shopping, house tours, and telemedicine services thrives, etc. This time of uncertainty is “disrupting” the modern workplace on a whole new level: policies and restrictions eliminated some jobs, made some go online (and some stayed online); managers and leaders are facing challenges such as lack of employee engagement, high turnovers, and more. According to the U.S. Bureau of Labor Statistics, over the month of November 2022, there had been 5.9 million cases of workplace separations, including 4.2 million quits, 1.4 million layoffs and discharges, and 0.35 million of other types of separations in the country. On the other side, there had been 6.1 million hires [1]. Although the pandemic did not start the resignations, it definitely spurred the “Great Resignation”, also known as the “Big Quit” or the “Great Reshuffle” [2], where people exited their current positions in a massive amount due to various reasons like relocation, reconsideration, reshuffling, etc. as described in a 2022 HBR article [3]. Turnovers add great costs to an organization (time invested in onboarding and training, loss of productivity, expenses to recruit and train new employees). Employees are always on the lookout for opportunities of better jobs, which does not just mean better location, benefits, or pays, but also means healthy organizational culture, engagement, job satisfaction, and opportunity for personal and professional growth.

Besides necessary on-the-job training, getting an advanced degree in relevant fields creates competitive advantages for both individuals seeking career advancements and organizations wanting to retain their best talents.

**Program Structure**

The Master of Engineering Technical Management program was created based on systematic research on industry needs in the technical management fields, through focus group discussions, surveys of stakeholders (prospective students, industry advisory board, interested subject matter experts, etc.), as well as extensive research on the job market. In 2018, METM officially launched and welcomed its first cohort of professional students. The program curriculum consists of 12 courses (Table 1) with a total of 30 credit-hours, which must be completed during a 21-month period, normally from August to May of the following year [4]. The curriculum integrates the domains of Engineering Management Body of Knowledge [5], bridging the workplace skill gap for people who are transitioning from entry level managers to middle-level managers and director-level positions by instilling students with both soft skills (leadership, communications) and technical skills (problem-solving, critical thinking) [6].

Table 1. METM Program Curriculum.

<b>Fall 1<sup>st</sup> Year</b>	<b>Spring 1<sup>st</sup> Year</b>
TCMT610. Engineering Personal Leadership (2)	TCMT623. Financial Decision Making (3)
TCMT612. Technical Management Decision Making (3)	TCMT624. Managing Technical Teams (3)
TCMT613. Technical Project Management (3)	
TCMT619. Personal Leadership Coaching (1)	
<b>Fall 2<sup>nd</sup> Year</b>	<b>Spring 2<sup>nd</sup> Year</b>
TCMT630. Organizational Leadership for Senior Technical Leaders (2)	TCMT641. Capstone Project II (3)
TCMT636. Persuasive Communications for Technical Managers (1)	TCMT643. Contract and Risk Management (3)
TCMT631. Capstone I (3)	
TCMT634. Value Chain Management (3)	

Note: Perspective credit hours are marked in parentheses following course names.

**Students Demographic**

Students enrolled in the METM programs are those who have or expect to have management responsibilities, as well as technical leaders at mid-level to senior-level positions. Based on data collected from application records and program exit surveys, these working professionals hold job titles like Lead Industrial Engineer, Project Manager, Mechanical Design Engineer, Maintenance Manager, Chief Technology Officer, Data Scientist, Civil Engineer, Director of Information Technology from various industries, for example, oil and gas, national laboratories, defense, aerospace, universities, non-profit organizations, etc. A summary of their demographic information is shown in Table 2 below. Among the total 207 METM students, the average age is 38 with a 1:2.67 female to male ratio and a diversified racial background.

Table 2. METM Students’ Demographics (Class of 2020-2024).

<i>Demographics</i>		<i>%</i>	<i>#</i>
Gender	Male	72.46%	150
	Female	27.54%	57
Age	Avg. age	n.a.	38.7
Veteran status	Yes	27.05%	56
Race	White	61.35%	127
	Hispanic	27.05%	56
	Black	5.80%	12
	Other	5.80%	12
		Total	207

**Course Design**

As shown in Table 1, TCMT631.Capstone I and TCMT641.Capstone II are completed sequentially in the fall and spring semesters; together, they are called “Capstone” (or “Capstone project”). As one of the final courses in the METM program, students must secure an industry-sponsored project to identify and address issues or concerns that will impact an organization financially or culturally [6]. The collaboration between industry and academia in capstone courses has been a well-grounded and mutually beneficial practice [7],[8], especially among

various engineering majors [9], [10]. For the Master of Engineering Technical Management program, common project themes include new product development, cost reduction, processes optimization, technical leadership development, etc., which are issues that become even more prominent during the time of uncertainty when organizations, regardless of their sizes, all try to navigate new and existing challenges and stay competitive.

During the nine-month Capstone project (normally from August to May), students go through a process that entails problem discovery, curated research, proper project design, data collection, and finally make feasible recommendations based on facts and analyses, and project implementation if time allows. This process requires many highly in-demand leadership skills, such as critical thinking (identify relevant information, process, people), communication (gain buy-in and update stakeholders), decision-making (prioritize and maximize resources), problem-solving (implement the best option) skills, just to name a few.

Below is a list of Capstone projects that were conducted by former METM students to demonstrate the wide range of industry-focused topics, which are extremely relevant to the challenges organizations currently face. A spectrum of skill sets in the Engineering Management Body of Knowledge (EMBOK) [5] are required in order to solve these issues, such as Leadership and Organizational Management, Project Management, Strategic Planning and Management, Financial Resource Management, etc.:

- RFID Real-Time Inventory Management Feasibility Study.
- Implementation of A Closed-Loop Gas Lift Optimization Solution Using Industrial Internet of Things (IIOT) Technology.
- Leveraging Organizational Behavior to Adapt to Market Paradigm Shifts.
- Establish and Define A Proper Cybersecurity Framework for Company A.
- Leadership Development using Emotional Intelligence Program to Improve the Overall Employee Satisfaction Rate and to Decrease Employee Churn.
- Usage of RFID tagging and Advanced Simulations to Reduce Maintenance Cost of Drill Pipe.
- Achieving Maximum Performance of A Batch Chemical Plant Through an Operational Excellence Center.

## **Definition of Terms**

In order to better understand the roles and responsibilities of the multiple parties involved in a Capstone project, the definition of terms is provided below (copied from course syllabus, “you” refers to students).

### *Industry Sponsor:*

An industry sponsor is a person from the organization that your Capstone project is aiming to solve a problem for or make improvement to. This is the person who will buy into your business case and sponsor your project for prospective benefits that you proposed.

### *Communications Professor:*

During Capstone I, professors who teach the course, Persuasive Communications for Technical Managers, will grade your PowerPoint slides and your oral presentations for your Capstone project. The goal is to help you communicate effectively with great persuasion. Communications professors are not involved in Capstone II.

### *Steering Committee:*

The steering committee consists of people who provide feedback to your Capstone project, including your industry sponsor, Communications professor and Capstone professor at a minimum. You can invite others who may have interest in your project.

## **Uniqueness of Capstone Design**

What is unique about the design of this Capstone course is that it has an auxiliary course during the first part of Capstone in the fall semester, which is “TCMT636. Persuasive Communications for Technical Managers” (or “Communications”), the detailed design of this communication course was introduced in Lu, Tingey, Preusser, & Zoghi [11]. The Communications professors serves as a “communication coach”, teaching students how to handle workplace scenarios such as negotiating for resources, conflict resolution, giving feedback, dealing with urgent situations, etc. through interactive role plays, and by offering constructive feedback on students PowerPoint slides and oral presentations in the Capstone course. Table 3 shows the list of deliverables students must complete throughout the duration of the two semesters with corresponding industry sponsor actions and Communications course supplementary.



Table 3. Capstone and Communications Class Deliverables.

<i>Capstone Deliverables</i>	<i>Industry Sponsor Role</i>	<i>Communication Supplementary</i>
Fall Semester		
[Project search]	[Sponsor search]	Two-day interactive workshop (Lectures, interactive role-plays)
Project Proposal	-	-
Literature Review for Business Case Development	-	-
Business Case (ppt and presentation)	Review and feedback on justifications of project	Feedback for communication improvement
Project Charter	-	-
Methodology	-	-
Project Plan (ppt, presentation, report)	Review and feedback on resources, process, risks	Feedback for communication improvement
Midterm Reflection	-	-
Spring Semester		
Data Analysis (ppt, presentation, report)	Review and feedback on collected data and insights, feedback on content	No Communication course in Spring
Decision Making Report	-	
Financial Analysis Report	-	
Final Presentation	Review and feedback on RIOs and Recommendations	
Final Report	-	
Final Reflection	-	

**Industry-Academic Collaboration for Project Success**

As shown in Table 3, many of the deliverables share the common format of the components of workplace projects, for example, Project Proposal, Business Case, Project Charter, Project Plan, Financial Analysis Report, etc. The intention is to use the familiar language universally used in the industry world so that learning is more relevant, and students

could apply these deliverables as templates or best practices when they lead an actual work project in the future.

The *industry sponsor* holds a critical role in this project-based course; he/she is expected to make their best effort to attend students' Capstone presentations and give feedback in a timely fashion at various checkpoints of the project. In most cases, they are those who hold a high up position in the organization that have formal authority to launch, monitor, facilitate, implement/champion the project and the one who is a direct stakeholder of the project. Before the fall semester starts, students must first search for a willing and committed industry sponsor; as a project unfolds, it normally involves setting up appointments with a senior manager or c-level executives, interviewing relevant personnel for data collection, reporting progress, presenting insights extracted from data, etc. Persuasive and effective communication skills to "up and across" are crucial to success; they directly impact whether a project will be approved or denied, allotted for more or less resources, given higher or lower priority and/or visibility in the organization, as well as affect how much data can be obtained from the targeted population depending on the effectiveness of the survey campaign, design of questionnaire and/or interviewing technique, etc.

The Communications course provided the much-needed coaching and practicing opportunities to students, especially those who work in the technical field (e.g. engineers) that are intelligent and data savvy, but do not have polished communication skills to be successful in a new leadership role. For example, in one of the interactive role-play scenarios, the student (team manager) need to request funds to buy a new machine to replace an old, glitchy one; the opponent in the scene, a division leader must push back the request or even deny it if the student cannot articulate valid reasons within a short time given to read the script (which has limited information, different for each role). Observers (students and a Communications mentor) will give feedback after the scene on the good and needs improvement areas regarding how information was interpreted, how conversation was carried out (body language, tone, choice of words, etc.), and how conflict/distraction was handled using emotional intelligence and problem-solving techniques learned from previous courses in the program (audience analysis, long vs short-term benefits analysis, etc.). These scenarios are as realistic as possible to simulate situations people might encounter at work where communication skills are key to success.

Besides coaching students in the interactive role-plays, Communications professors also critique students' PowerPoint slides and attend presentations of their Capstone project deliverables (see Table 3). Their feedback focuses on the visual design and logical flow aspects, for example, the use of design elements, e.g., font, colors, white space (are they consistent or burdening the audience), the clarity of charts and figures (are they adding value or causing confusion), the structure of content (are they cohesive and complete), as well as how the presentation is delivered (is it telling a compelling story to persuade the audience, how the verbal and non-verbal language are utilized). The intention is that the coaching and feedback will provide immersive learning and practicing opportunities for immediate application and improvement on communication skills. The theoretical framework, structure and learning activities of the Communications course can be found in Lu, Tingey, Preusser, and Zoghi [11].

### **Assessments of Learning Outcome**

#### **Course Evaluation (Fall 2022)**

Course Evaluation Survey was sent to students who are enrolled in the Capstone course towards the end of the fall semester, among which 14 out of 38 responded to the anonymous questionnaire. Table 4 below listed questions that are pertinent to students' learning outcomes in a descending order by the average rating. Due to the fact that different scales were used, ratings were converted by calculating the percentage of average rating over maximum possible score. Based on the responses, students reflected highly of their own level of participation in the learning activities, and that they were frequently engaged in critical thinking and/or problem solving, they also firmly understood what was expected of them for the course. These questions have ratings that are over 90% of the maximum possible scores. The questions with lower scores are regarding course organization, helpfulness of the feedback received, and the opportunity to evaluate diverse ideas and perspectives (all below 85% of maximum scores); these are the aspects of the courses that need attention for the next offering.

Table 4. Course Evaluation Survey Results - Fall 2022.

Question statement (N=38, n=14)	Rating Max	Avg. rating	% of max
Begin this course evaluation by reflecting on your own level of engagement and participation in the course. What portion of the class preparation activities and assignments did you complete? [1 = <50%... 4 = >90%]	4	4.00	100.00%
In this course, I engaged in critical thinking and/or problem solving. [1 = Never...4 = Frequently]	4	3.64	91.09%
Based on what the instructor(s) communicated, and the information provided in the course syllabus, I understood what was expected of me. [1 = No...3 = Yes]	3	2.72	90.50%
This course helped me learn concepts or skills as stated in course objectives/outcomes. [1 = Did not help... 4 = Definitely helped]	4	3.50	87.52%
Please rate the organization of this course. [1 = Not at all organized 4 = Very well organized]	4	3.36	83.91%
Feedback (formal and informal) in this course helped me learn. [1 = No feedback ...6 = Feedback was extremely helpful]	6	5.00	83.33%
In this course, I learned to critically evaluate diverse ideas and perspectives. [1 = Strongly disagree 6 = Not Applicable]	5	4.07	81.44%

### Students Written Reflections

By the end of the Capstone I semester, students reflected on their journey of the Capstone project, i.e. how they secured their project, asked for upper management feedback, and applied previously learned knowledge (e.g. emotional intelligence, technical knowledge), etc. through a Midterm Reflection (Table 3). While the voluntary course evaluation survey received less than 40% of responses, this written reflection was a required assignment, thus, it collected additional qualitative data to gauge students' learning outcomes at this point of time. This exercise provides opportunities for internalizing individual personal and professional growth and paves the way for better actions moving forward. Quotes from students' written reflections are categorized into the area of development as listed below.

#### *Project Management*

"I secured my project within my company by communicating with peers, mentors, leaders, and my extended network about daily sore spots and any concerns for the future."

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“Throughout this program, I learned the importance of buy-in and cooperation from all parties to achieve organizational cohesion and success.”

### *Leadership, Emotional Intelligence*

“I now understand it pushes us to work at the next level, so we are prepared for those tasks that come with promotions to any upper management level.”

“The tools I have garnered throughout the METM program have allowed me to overcome some of my biases and, most certainly, personal emotions that might have hindered the project.”

### *Communication and Collaboration*

“The capstone process has been very enlightening. It has been a fantastic opportunity to communicate with a broader audience on innovative ideas and collaborate with new work groups”

### *Problem Solving*

“I found communication with them was most successful when I came up with a solution and then they molded that solution with their own experiences and perspective. My method of gathering advice was to ask big-picture questions about impact and multifaceted improvement.”

### *Critical Thinking/analysis skills*

“Having a capstone project that benefits his (industry sponsor) organization gives him a return on his investment, and I gain visibility as a division employee.”

“The most helpful assignment this semester has proven to be the literature review for the business case. This aided me in collecting preliminary information on my project that paid dividends in each additional assignment. Through this assignment, I was able to explore a substantial body of information which ultimately matured into my project’s cultural framework for healthy culture and healthy attrition.”

## **Masters Graduation Survey**

Before graduating from the METM program, all students are invited to fill out an anonymous Masters Graduation Survey conducted by the university. A few relevant questions

from the “Learning Outcome” question block were selected from the 70+ questions asked in the survey; other question blocks include categories such as Climate and Obstacles, International Experience, Post-Graduation Plan, Professional Development, etc. The ratings range from “None, Very little, Some, Quite a bit, to Very much”; the percentage was calculated as the sum of “Quite a bit” and “Very much” to capture the portion of students who felt positively agree with the statements.

Three academic years of data (AY 2019-2020, 2020-2021, 2021-2022) were retrieved for the purpose of this study. Both METM data and a combined result from other online programs offered within the same department (“Non-METM Combined”) were collected. The non-METM students are a combination of three similar degree programs, ENTC (Engineering Technology), MID (Master of Industrial Distribution), MMET (Manufacturing and Mechanical Engineering Technology (MMET)). Both groups receive the same survey during the same time period.

Table 5 shows a summary of survey responds statistics. Both groups are similar in comparison of the total survey respondents (N) and number of students who positively agreed with the three statements (n). The decision to use combined results for Non-METM programs was to compare two groups with similar group size. Admittedly, neither group received large quantity of responses due to the survey being voluntary and anonymous. The goal of looking at the data sets was not focused on comparing the two groups (differ in course offerings and students’ demographics), but to benchmark the effectiveness of the unique METM curriculum on a department level.

Table 5. Comparison of Summary Statistics of Masters Graduation Survey-Learning Outcomes-METM vs. Non-METM Combined (AY19-22).

<b>My ability to communicate effectively with colleagues.</b>						
Academic Year	METM	n	N	Non-METM Combined	n	N
AY19-20 %	72.73%	8	13	100.00%	8	10
AY20-21 %	75.00%	6	11	83.33%	5	9
AY21-22 %	80.00%	12	19	84.21%	16	23
<b>My ability to communicate effectively with lay persons.</b>						
Academic Year	METM	n	N	Non-METM Combined	n	N
AY19-20 %	63.64%	7	13	100.00%	8	10
AY20-21 %	62.50%	5	11	66.67%	4	9
AY21-22 %	80.00%	12	19	89.47%	17	23
<b>My ability to write effectively.</b>						
Academic Year	METM	n	N	Non-METM Combined	n	N
AY19-20 %	63.64%	7	13	87.50%	7	10
AY20-21 %	75.00%	6	11	83.33%	5	9
AY21-22 %	86.67%	13	19	78.95%	15	23

In Figures 1-3, METM data are represented by blue bars, and Non-METM Combined are represented by red bars, and they were compared across three academic years. Note that while Capstone had been offered in all three academic years, the Communications course was not offered in AY19-20, or AY20-21; it was a new addition to the AY21-22. A trend can be observed from the blue trendlines (METM) in Figures 1-3 that METM students' perceptions of their abilities in communications with colleagues and lay persons and writing effectively had been improving over time, and it is very likely that the addition of the Communications course had brought positive change to the communication skills below; however, there are no drill down questions, thus, this is only an implication. Additionally, looking at the red trendlines (Non-

METM Combined), the same satisfaction scores had been on the decline for similar online programs.

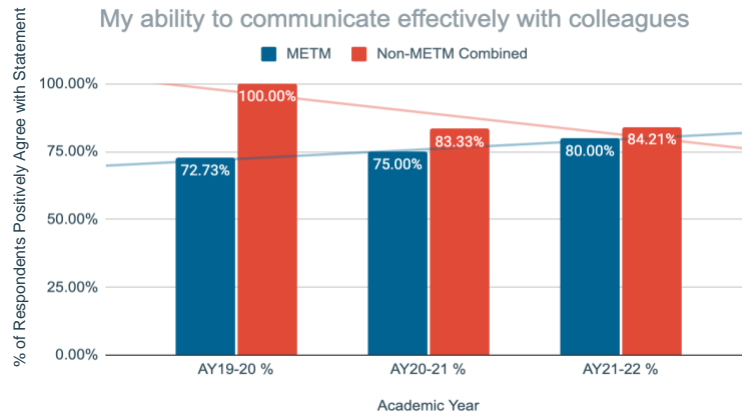


Figure 1. Master’s Graduation Survey Results- Communication with Colleagues, METM vs. Non-METM, AY19-22.

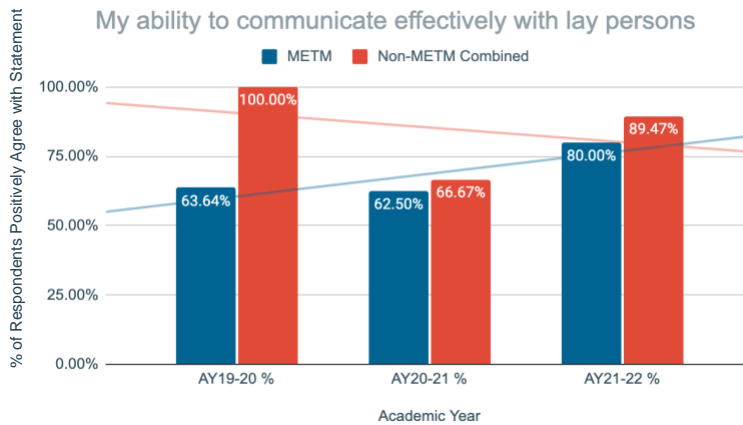


Figure 2. Master’s Graduation Survey Results- Communication with Lay Persons, METM vs. Non-METM, AY19-22.



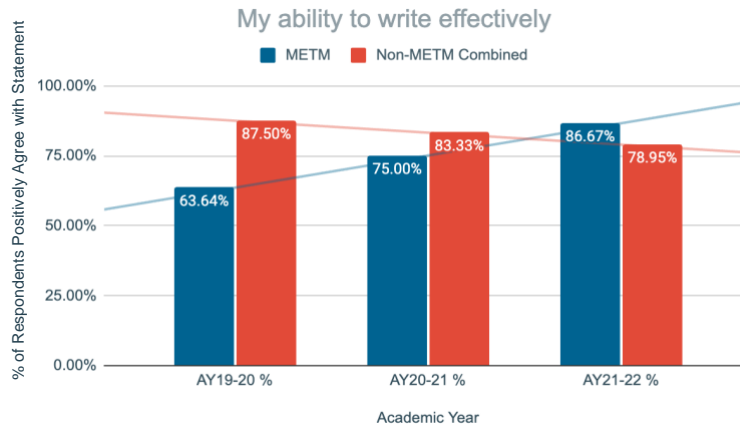


Figure 3. Master’s Graduation Survey Results- Effective Written Communication, METM vs. Non-METM, AY19-22.

### Implication and Conclusion

The Capstone course is delivered online, where students learn course content at their own pace; presentations on various reports are conducted online via Zoom. The remote delivery format of the course enables students to balance their work, life, and study based on their unique schedules; during the time of a global crisis, the disruption to learning brought by COVID-19 has been minimized since the majority of the work does not need to be done in a face-to-face setting.

Under the guidance of Capstone and Communications professors and the support from their industry sponsors, by going through the process of problem identification, research, data collection, data analysis, financial analysis, and decision making, professional students were able to apply technical knowledge learned throughout the online Master of Engineering Technical Management program into their Capstone projects. In the meantime, through the interactions, presentations, and written reports, students had further advanced skills such as communications, leadership, and emotional intelligence. Based on quantitative data collected from the past graduating cohorts, the perceived growth in their ability to communicate effectively with colleagues and lay persons has been on the rise in the past three years, especially after the Communications course was added to the curriculum in the third academic year (2021-2022).

As discussed, students recognized the invaluable impact that Capstone projects had brought in terms of professional and personal growth, but there is always room for

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enhancements: we are currently in the process of evaluating both the Capstone and Communications courses; a major upgrade is in the work and is expected to bring improved structure, richer content, and better learning outcomes; furthermore, we are working on better survey questionnaires to tackle the low response rate issue of the Masters Graduation Survey.

This uniquely designed online Capstone course craftly weaves industry-standardized project components into academic research and utilized a communication course to coach students to effectively communicate with key project stakeholders; it is a perfect demonstration of industry-academic collaboration for student success, in this case, working professionals in the engineering technical field. The course design could also provide insights for other institutions who aim at offering similar courses.

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