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CONTINUOUS IMPROVEMENT IN AN ENGINEERING TECHNOLOGY CAPSTONE SEQUENCE

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This paper outlines the continuous improvement enhancements of a two-semester multidisciplinary capstone program tailored for senior students within the School of Engineering Technology. These courses revolve around collaborative teamwork and focus on the development of innovative solutions for industry-sponsored projects. The overarching goal of these courses is to facilitate a seamless transition for students into their professional careers. One area that students often struggle with is developing professional skills (including communication and teamwork), which are required components evaluated in ABET accreditation and are necessary for graduates as they begin and progress across their careers.

The Plan-Do-Check-Act continuous improvement process was used to develop, deploy, and evaluate a series of interventions to enhance the overall Capstone Education experience. This design case will particularly focus on interventions related to fostering professional skills.

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INTRODUCTION

The Accreditation Board for Engineering and Technology (ABET) accredits degree programs in engineering technology. Accreditation criteria for engineering technology degree programs include student outcomes, emphasizing the professional skills of effective communication (Outcome 3) and teamwork (Outcome 5) ("Criteria for Accrediting Engineering Technology Programs, 2024–2025," 2021).

The School of Engineering Technology (SoET) uses a continuous improvement process to evaluate student outcomes data that is used for ABET accreditation. The 2016-17 ABET review identified areas of concern in the quality of capstone written reports and teamwork assessment. This paper presents a series of interventions to improve the capstone educational experience for the students in the SoET, focusing on teamwork assessment and written quality of capstone reports.

Capstone education in SoET offers senior-level students a unique opportunity to apply the knowledge and skills they have acquired throughout their program to real-world engineering projects (Howe et al., 2017; Moore & Berry, 2001). These courses are designed to be a culminating experience for students in engineering technology, allowing them to synthesize their learning and demonstrate their capabilities (Paretti et al., 2019)

Typically, capstone projects require students to collaborate with industry partners and involve designing, building, testing, and delivering a working prototype that addresses a specific engineering challenge. Through these projects, students gain hands-on and minds-on experiences that prepare them for the demands of professional practice.

The goal is to empower students to take charge of their learning journeys, fostering independence, critical thinking, and collaboration. Additionally, ongoing enhancements will be made to integrate feedback mechanisms such as CATME (Comprehensive Assessment of Team Member Effectiveness) reflections, ensuring that students continue to

actively engage in the continuous improvement of their own educational experiences (Beigpourian et al., 2019).

This paper will discuss the history of the course revision process focused on students' development of professional skills, since 2016. We will discuss the *Foundations* (the prior history of the course and the reason to begin interventions), the *Implementation and Impact* of changes made across the years this team has used a Plan-Do-Check-Act process for continuous improvement, and the *Future Directions* of the course.

CONTEXT

The SoET facilitates a two-semester multidisciplinary capstone experience for students in the final year of their undergraduate degree program. The two courses that comprise the capstone sequence are centered on student teams collaboratively designing and developing innovative solutions for industry-provided projects. The primary objective of these courses is to assist students in smoothly transitioning into their professional careers.

The first course in the two-course sequence is 3-credit hours, comprising two 1-hour lecture periods and one 2-hour laboratory period. The second course is also 3 credit hours, consisting of one 1-hour lecture period and two 2-hour laboratory periods. Faculty members (including the first author), alongside academic mentors—who are typically either current faculty with relevant experience or retired engineers—offer specialized support tailored to the demands of these capstone projects. This ensures that students not only gain from real-world expertise but also receive academic guidance tailored to engineering challenges.

The curriculum is further enriched by contributions from the College of Education and the University Library. Experts in learning design from the College of Education (including the second and third authors) focus on the crucial aspects of self and peer feedback, teaching students how to critically evaluate their work and that of their peers. Meanwhile, faculty from the University Library introduce essential information literacy skills, ensuring students can effectively gather, assess, and apply information in their projects.

This concerted effort by faculty from three distinct colleges within the university is designed not just to impart knowledge but to significantly enhance the overall learning experience for students undertaking the SoET capstone courses. The goal is clear: to prepare students for the complexities of real-world engineering challenges through a pragmatic, collaborative, and interdisciplinary approach.

Students spend two semesters working in teams on an industry-sponsored project. Each sponsor provides at least one "industry mentor" to work with their student team. Industry mentors are typically engineers working at the sponsoring companies and are often alumni who would like to give back to their alma mater.

	18-19	19-20	20-21	21-22	22-23
ECET	67	50	40	42	34
MET	20	49	67	88	79
MFET	22	39	47	41	37
IET	7	39	64	73	59
Other			8	3	17
TOTAL	**116**	**177**	**226**	**247**	**226**

TABLE 1. Capstone Enrollment by SoET Program

ECET: Electrical & Computer Engineering Technology;
MET: Mechanical Engineering Technology;
MFET: Manufacturing Engineering Technology;
IET: Industrial Engineering Technology;
Other: Students Not In SOE

	18-19	19-20	20-21	21-22	22-23
Projects	23	29	41	43	45

TABLE 2. Capstone Projects.

	18-19	19-20	20-21	21-22	22-23
Team Size	4-6	5-7	6-8	6-8	6-8

TABLE 3. Capstone Team Size.

Apart from attending the mandatory lectures and laboratory sessions, each team is required to hold weekly meetings with their academic and industry mentors, which typically last up to an hour. During these meetings, students provide progress updates, and the industry and academic mentors offer valuable feedback.

The capstone process involves progressing through a stage/gate framework, with Gates 1-3 completed in the first course and Gates 4-6 addressed in the second course, leading to the final deliverable. Tables 1-3 provide contextual information on the multidisciplinary capstone project experience offered by the SoET. These tables display enrollment figures by major, the number of capstone projects undertaken, and the team size range.

PLAN-DO-CHECK-ACT

The Plan-Do-Check-Act (PDCA) approach was employed as a means of continuously improving the multidisciplinary capstone course sequence (Morgan & Stewart, 2017). The selection of the PDCA approach as the continuous improvement tool stemmed from its well-established use in industry and its familiarity the industry mentors and academic mentors. The PDCA approach consists of four repeated stages to drive continuous improvement:

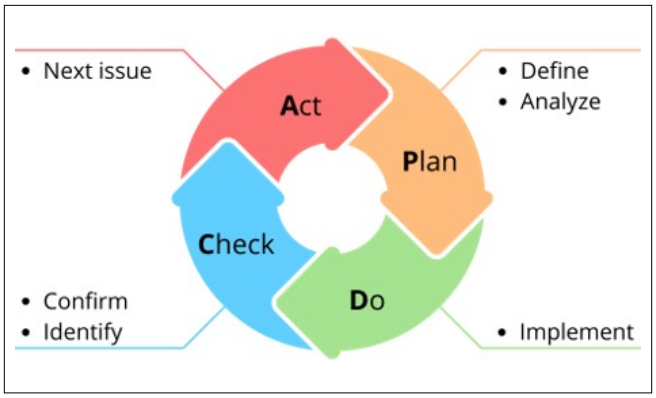

FIGURE 1. The PDCA Cycle (Morgan & Stewart, 2017).

- **PLAN:** Identify the problem, gather data, and develop a plan to address the problem.
- **DO:** Implement the plan by carrying out the steps identified in the planning stage.
- **CHECK:** Evaluate the implementation results by measuring the outcomes against the criteria established in the planning stage.
- **ACT:** Take action to improve the process or system based on the findings of the previous three stages, which may involve adjusting the plan.

By repeating these stages, the learning experience for the SoET capstone students was continuously improved. The PDCA cycle is shown in Figure 1.

FOUNDATIONS PHASE: HISTORY OF THE CAPSTONE COURSE SEQUENCE

In 2012, the SoET initiated efforts to incorporate real-world, immersive capstone experiences as a culminating project in the final year of the undergraduate degree experience. These projects aimed to provide students with experience working alongside industry partners to solve complex problems. By the fall of 2016, students in the Electrical and Computer Engineering Technology (ECET) and Mechanical Engineering Technology (MET) programs were working together in multidisciplinary groups engaging in these capstone courses, with plans to extend the initiative to the Industrial Engineering Technology (IET) and the Manufacturing Engineering Technology (MFET) programs by 2018.

However, by the end of 2017, it became apparent that many students were unclear about the value of collaborating with peers from other majors on capstone projects. A preference for discipline-specific projects emerged among students and was echoed by some faculty members, who believed that focusing within their fields would better serve their students' educational and career goals.

The ABET review of 2016-17 underscored this sentiment by highlighting shortcomings in teamwork and the quality of capstone reports, serving as a critical wake-up call to the multidisciplinary approach of the capstone experience. This feedback prompted a reevaluation of how capstone projects are structured in the SoET, with an ongoing effort to balance the benefits of multidisciplinary collaboration with the need to address discipline-specific competencies. The following sections describe these changes, which occurred iteratively across and within each academic year from 2017 to the present.

A high-level outline of the capstone program is presented below, illustrating how the two courses were managed during 2017-18. Again, Gates 1-3 were completed in the first course and Gates 4-6 were completed in the second course. This Stage/Gate framework spans across both capstone courses, with a total of 6 Gates. This process was designed to structure the progress of capstone projects through a series of checkpoints. Each gate serves as a milestone requiring specific deliverables, including live bench demonstrations, written reports, and oral presentations.

Gate 1 Outline

During the first week, students receive a project catalog for review. After reviewing the catalog, they were asked to submit a list of their top seven projects. A CATME TeamMaker survey was sent to the students, which was used to start the team-making process (Meulbroek et al., 2019).

During the second week, the teams begin weekly meetings with their academic mentors and arrange their first meeting with industry mentors.

By the third week, the Gate 1 deliverables were presented, typically including a scope of work and project requirements. To produce these deliverables, students needed to collaborate with their industry and academic mentors to gather relevant information and share ideas.

The Scope of Work is a narrative description of the project's requirements matrix. It defines project-specific activities, deliverables, and timelines of the team's plan to service their industry mentors.

The Project Requirements Matrix is a technical metrics record defining product features and functionality requirements.

During the fourth week, the teams begin creating their work breakdown structures (WBS). They also present draft versions of their scopes of work and project requirements matrix to their industry and academic mentors for feedback.

The WBS is a hierarchical structure that starts with the overall project at the top and then breaks it down into smaller and smaller tasks or sub-tasks, each with specific deliverables, timelines, and resources (Howe & Goldberg, 2019).

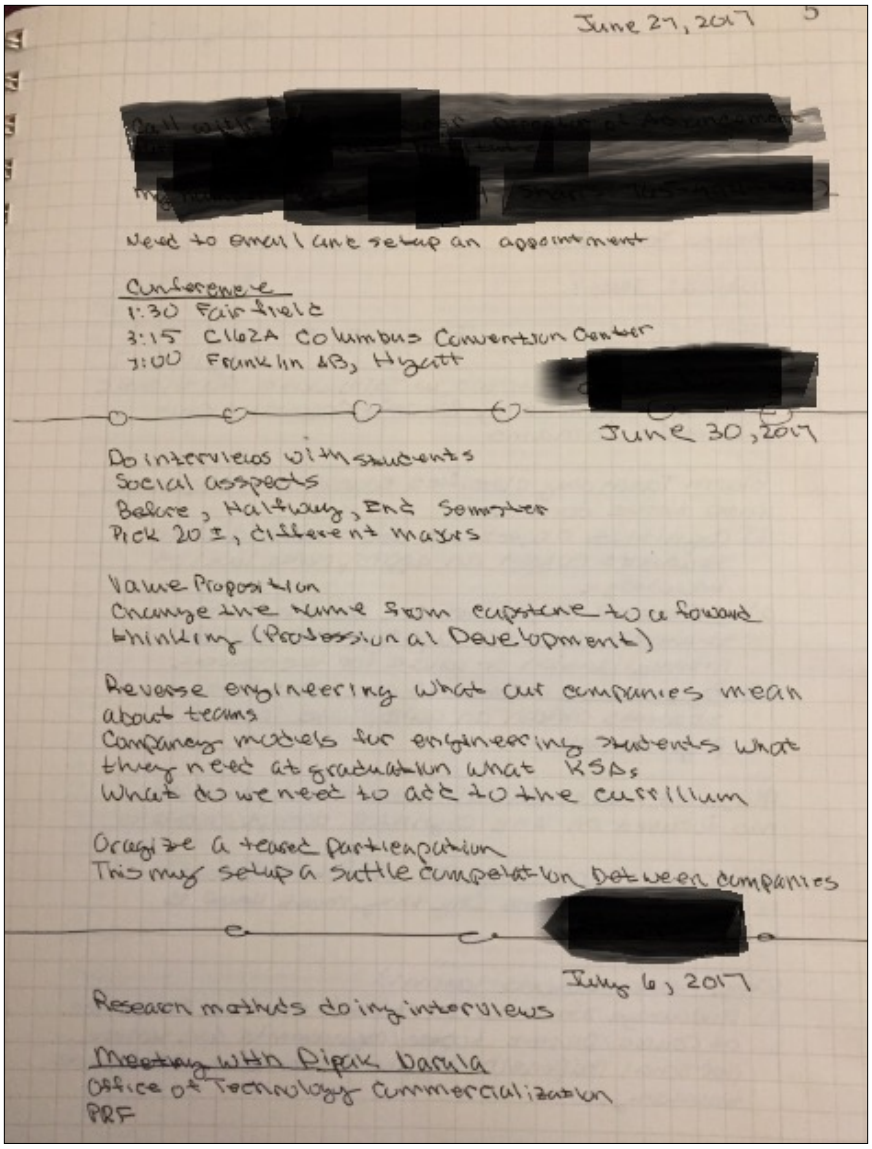

FIGURE 2. Bound Lab Notebook—Each student was required to take notes by hand of test results, meeting minutes, assigned tasks, etc. daily.

During the fifth week, teams submit their Gate 1 reports for grading, which are team assignments. Also, each student submitted a lab notebook, which are individual assignments. These assignments consisted of bound lab notebooks. All entries were written in permanent ink, with no blank pages or gaps on any page, and all entries must be dated, see Figure 2.

In addition, students participated in self-and-peer assessment using CATME, an online tool designed for students to provide their peers with feedback on their team skills and help them develop more effective collaboration practices (Berry et al., 2022)

The CATME assessments of the teamwork dimensions (CATME Teamwork Rating Scale, n.d.) are collected every five weeks, which are C) Contributing to the Team's Work, I) Interacting with Teammates, K) Keeping the Team on Track, E) Expecting Quality, and H) Having Relevant Knowledge, Skills or Attributes.

Gate 2 Outline

During the sixth week, the students develop concept designs, critical issue identification, and resource availability analysis. Concept designs are explained through initial analytical calculations, CAD models, and other supporting methods to advance design options. Critical issues are identified, and the necessary information and supplies for the project and the means to obtain them are determined. An analysis of resource availability is conducted to ensure all the resources needed for project completion are in place.

In the seventh week, the students continue to work on developing their conceptual designs. Also, teams refine their project's WBS.

During the eighth week, the topic of down-select is introduced. Down-select refers to the process of reducing the number of potential options or alternatives based on specific criteria.

During the ninth week, the students send draft versions of their team's conceptual designs to their industry and academic mentors for feedback and suggestions.

During the tenth week, teams submit Gate 2 reports. Also, each student submits a lab notebook. Students participate in self-and-peer assessment using CATME. Additionally, each team has a juried critical design review presentation. The critical design review is an hour-and-a-half juried presentation. The judges for this review are the industry and academic mentors, as well as the academic mentors.

Gate 3 Outline

During the eleventh week of the course, students are tasked with developing detailed designs as part of Gate 3. The main goal of Gate 3 is to produce the team's minimally valuable product (MVP), which meets all project requirements. The MVP is the most basic product version that provides the essential functionality needed to create a working

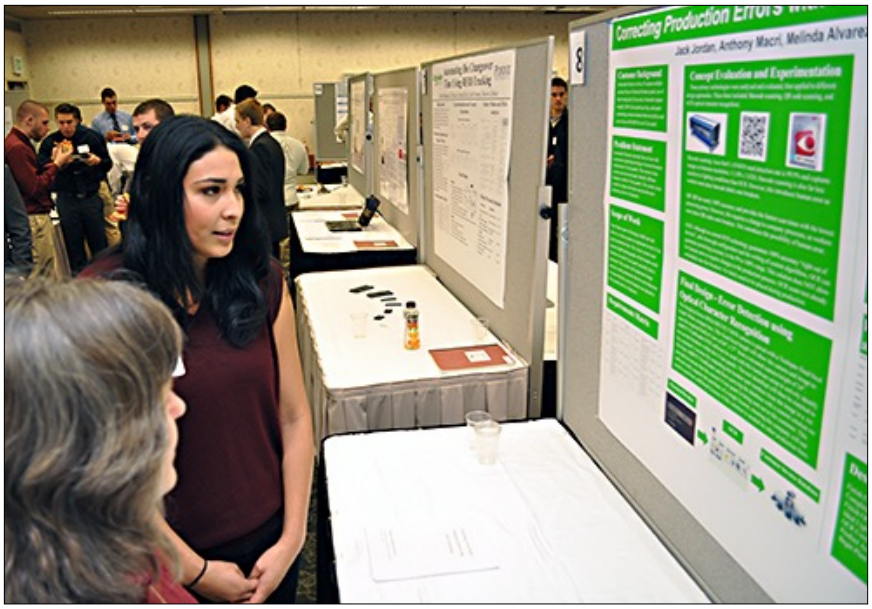

FIGURE 3. Gate 3 Poster Presentation (Lincoln, 2015)—capstone clients, faculty, and students were invited to attend a poster presentation on campus in which capstone students presented their mid-project results.

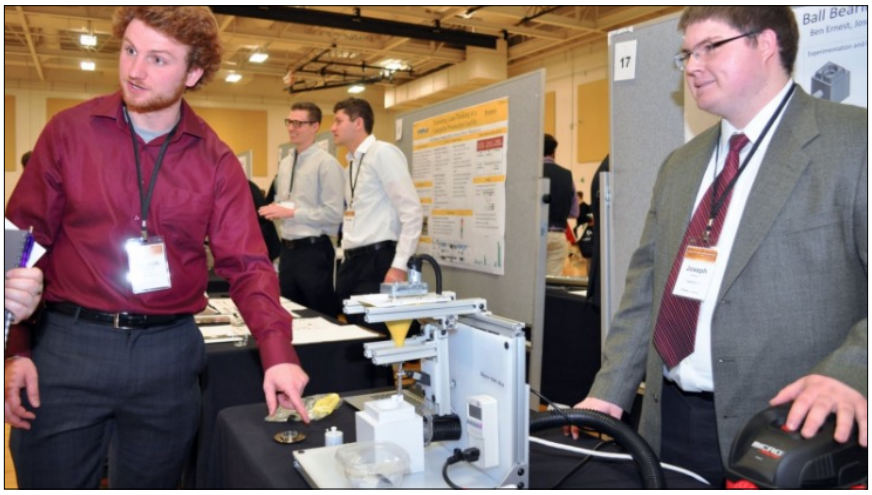

FIGURE 4. Gate 6 Poster Presentation (O'Malley, 2019) - Capstone clients, faculty, and students were invited to attend a poster presentation on campus in which capstone students presented their final project results.

prototype that satisfies the requirements in the requirements matrix (Lenarduzzi & Taibi, 2016).

In weeks 12–14, students continue working on their MVP, while creating BOMs (bill of materials) specifying vendors and suppliers (Cunningham et al., 1996). Additionally, the topic of failure modes and effects analysis (FMEA) is introduced. FMEA is a systematic method for identifying and prioritizing potential failures in a system or process, as well as developing a plan to mitigate or eliminate those failures (Carbone & Tippett, 2004).

In week 15, all students participate in a poster session, see Figure 3. The capstone team unveils their detailed project designs, which mimic a professional conference atmosphere. The event hosts a diverse audience, including project clients, fellow students, faculty, and industry professionals, to explore and interact with the teams.

In week 16, the Gate 3 report and lab notebooks are submitted for grading, and CATME is administered to the students.

Gate 4 Outline

In weeks 17 to 19, the teams complete their final detailed designs, which include:

- Plan to resolve all critical issues
- Full mechanical, electrical, and software documentation
- Final design calculations
- Final test plan to verify all project requirements are met
- Final bill of materials

In week 20, another critical design review takes place where the teams present their final detailed designs and final BOMs.

In week 21, teams submit Gate 4 reports and their lab notebooks. Again, students participate in self-and-peer assessment using CATME.

Gate 5 Outline

In weeks 21 to 25, students devote much of their time to building, testing, and reporting project progress to their mentors.

In week 25, teams submit Gate 5 reports and their lab notebooks. Again, students participate in self-and-peer reviews using CATME.

Gate 6 Outline

In weeks 25 to 30, teams complete their projects and prepare their final report and poster presentations, see Figure 4.

In week 30, a poster presentation occurs where the teams present the final version of their capstone projects (see Figure 4). The Gate 6 poster session has the same format as the Gate 3 poster session. However, the capstone teams present their projects from initiation to completion, including lessons learned, project documentation, and recommendations for future work.

In week 31 (Finals), teams submit Gate 6 reports and their lab notebooks. The final self-and-peer review using CATME is administered to the students.

AREAS OF CONCERN

In the academic year of 2016-17, the SoET continuous improvement process noted areas of concern, notably the quality of capstone written reports and the effectiveness of teamwork assessments. This process led faculty members to undertake a thorough review of capstone reports and CATME peer feedback during the summer of 2018, analyzing submissions from the previous two years to identify and address the root causes of these concerns.

Writing

The analysis of capstone reports showed that the primary challenge hindering student writing was not the mechanics of grammar, spelling, or punctuation but rather the coherence of their submissions. This manifested in various ways, including incomplete report sections, inadequately conducted literature reviews, and a significant lack of data to support conclusions (Berry et al., 2021a). These issues collectively resulted in a disjointed report structure, obscuring the core message and diminishing the clarity of these reports.

Two main factors contributed to this lack of coherence. The first was the superficial understanding of their projects by the teams, which was directly reflected in their writing. This indicated a collective gap in comprehending the full complexity and nuances of their projects (Berry et al., 2021a). The second factor was the piecemeal approach to composing the report, with different team members writing separate sections independently and merging them at the last moment. This process, devoid of a comprehensive final review and editing to ensure consistency and coherence, led to a fragmented narrative that undermined the quality and effectiveness of the submissions.

Teamwork

Simultaneously, faculty members' review of CATME peer feedback revealed an intriguing trend: students' inflated expectations for performance ratings. Despite a significant number of students performing at lower levels (receiving ratings of 1 or 2), the majority were awarded high scores (4s and 5s). Additionally, some students advocated for creating additional rating levels above 5 ("superior") to acknowledge peers who exceeded expectations (Berry et al., 2022). However, this suggestion revealed a fundamental misunderstanding of the rating system's purpose and the significance of each score.

In response, the faculty chose to refrain from introducing more rating levels, understanding that such a change would not tackle the core issue. Instead, this scenario underscored the necessity for clearer communication and education regarding the objectives of the rating system and the criteria for each score. The goal was to recalibrate students' expectations and cultivate a more nuanced understanding of the distinctions between meeting, exceeding, and truly surpassing expected behaviors (Berry et al., 2022).

By addressing these identified concerns, the faculty aimed to enhance the coherence and depth of capstone reports and refine the teamwork assessment. This ensured that students' ratings accurately reflect their contributions and understanding of collaborative efforts. This comprehensive approach marked a significant step towards elevating the educational quality and integrity of the capstone experience.

IMPLEMENTATION & IMPACT PHASE

Interventions 2018-19

In the 2016-17 academic cycle, a thorough review of the capstone courses yielded several pivotal observations. It led to impactful interventions to enhance the educational experience and outcomes for capstone students. Here is an account of the observations and the subsequent actions taken:

OBSERVATION 1 (ACT-PLAN): The critical design reviews at Gate 2 emerged as a vital platform for students to present their project ideas and receive constructive feedback. This process was instrumental in enabling teams to refine their Gate 2 reports significantly, thereby deepening their project comprehension and engagement.

OBSERVATION 2 (ACT-PLAN): Despite the Gate 3 poster presentation offering valuable networking opportunities, it became apparent that the progression of capstone projects stalled somewhat after Gate 2, with many teams showing only incremental advances. This lull in momentum suggested a need for a reevaluation of the milestone structure to maintain student engagement and project development continuously.

OBSERVATION 3 (ACT-PLAN): A closer inspection by week 5 of the second semester revealed that several teams were yet to move beyond the design phase. The proximity of Gate 6 compelled a hastened completion effort, often leading to rushed decisions that compromised project quality.

OBSERVATION 4 (ACT-PLAN): Collecting and grading lab notebooks three times per course proved insufficient for a thorough assessment of individual efforts and for providing timely, constructive feedback.

INTERVENTION 1 (DO): In collaboration with the University Libraries faculty, a curated Library Course Site was developed, tailored to support the specific needs of capstone students in their capstone endeavors (Phillips & Huber, 2022).

FIGURE 5. Tech Expo (Pompella, 2023)—Students showcase their final working capstone projects, which is open to the public in a face-to-face and online Tech Expo.

This innovation directly aligned with the sections in the Gate reports, facilitating more accessible access to pertinent information and resources.

IMPACT (CHECK): The Library Course Site's integration heralded the creation of a structured Learning Management System (LMS) platform specifically for capstone students. This platform featured report templates, rubrics, sample reports, assignments, and lecture materials linked for pre-class review. This strategic organization of resources significantly clarified expectations for reports and presentations, enhancing student preparation and project outcomes.

INTERVENTION 2 (DO): Acknowledging the need for progress between Gates 2 and 4 and the impractical timing of Gate 4 for final designs and ordering parts, the faculty restructured the reporting and review timeline. The faculty introduced Gates 1.5 and 2.5 for additional oral critical design reviews and adjusted the scheduling of reports and design phases to ensure a smoother progression of project milestones.

IMPACT (CHECK): This restructuring led to a more evenly spaced series of reporting and review points across both courses, ensuring continuous engagement and providing regular feedback opportunities. Moreover, positioning the poster presentation after the second course during the Tech Expo (Figure 5) offered students a public platform to showcase their final projects, further enriched by a parallel virtual Tech Expo featuring videos from Gates 4.5 and 5.5.

INTERVENTION 3 (DO): Transitioning from traditional lab notebooks to formal project notes allowed for a more dynamic and detailed submission process. This approach enabled the inclusion of diverse multimedia elements, offering a richer perspective on each student's contributions and progress.

IMPACT (CHECK): The shift to project notes significantly enhanced the assessment process, providing instructors with a comprehensive view of students' efforts and achievements. This allowed for more focused feedback and evaluations, creating a more personalized and effective learning experience.

Through these interventions, the faculty aimed not only to address the identified challenges but also to foster an environment of continuous improvement and innovation. These efforts reflect a commitment to enhancing the educational journey for capstone students, preparing them for successful futures in their respective fields.

Interventions 2019-20

OBSERVATION 1 (ACT-PLAN): After successfully providing report templates, report rubrics, and sample reports to the students, the instructors planned to improve team and instructor collaboration on the reports and focus on writing. Here is an account of the subsequent actions taken:

INTERVENTION 1 (DO): This initiative focused on facilitating iterative writing and feedback for all Gate reports (Berry & Carlson, 2010), (Berry & Carlson, 2005). Coursework (CWs) was developed where each student and each team had to write sections of their Gate 1 report and submit them for review and feedback. For example, CW 24 and CW 25 worked together in the following way. CW 24 required each student to review the literature and create annotated bibliographies of several sources. CW 25 then required the team to review the annotated bibliographies and create a state-of-the-art statement for their Gate 1 capstone project. As the teams moved from gate report to gate report old sections were updated and improved as new sections were added.

IMPACT (CHECK): In the writing assignments for each section of the Gate reports, teams received valuable feedback, enabling them to make necessary improvements before the final grading. This iterative process was sustained throughout both courses, fostering ongoing learning and development in written communication. In addition, the team writing and the individual writing became balanced in that, the point values for the project notes were to equal those of the Gate reports.

Interventions 2020-21

The provision of writing support was continuously observed to be successful, as highlighted in observations 1 and 2. However, an improvement in peer and self-assessments was deemed necessary, as indicated by observation 3. The impact of COVID-19 on the final five weeks of the spring semester was significant, yet the resilience demonstrated in observations 4 and 5 was notably gratifying. Here is an enhanced account of these observations and the subsequent actions that were undertaken:

OBSERVATION 1 (ACT-PLAN): It was observed that feedback provided on the writing assignments for each section of the Gate reports enabled teams to make essential enhancements prior to the final evaluation. This iterative process was maintained throughout both courses, promoting continuous learning and development in written communication skills.

OBSERVATION 2 (ACT-PLAN): Despite the challenges posed by the pandemic, it was observed with satisfaction that all capstone teams completed their projects to the best of their abilities. The commitment shown by students, industry mentors, and instructors to continue with the courses was commendable. Nearly all students attended the scheduled meetings, and those unable to attend, communicated their reasons to their teammates and instructors. Although all sponsoring companies had transitioned their staff to remote work, it was remarkable that industry mentors persisted in collaborating with their teams online from their homes.

OBSERVATION 3 (ACT-PLAN): Reviews of self-and-peer assessment written feedback in CATME indicated a need for students to learn how to provide meaningful and constructive feedback based on the CATME dimensions.

INTERVENTION 1 (DO): Acknowledging the significant stress induced by COVID-19 as students commenced their capstone in spring 2021, a team-building activity known as the Marshmallow Challenge was introduced (McClelland, 2023). This was made possible because the spring cohort, consisting of 50 students, could be accommodated within a large lecture room.

IMPACT (CHECK): The Marshmallow Challenge, which required students to construct a tower using spaghetti to support a marshmallow, was effective and enjoyable, receiving overwhelmingly positive feedback. This challenge has been adopted as an introductory activity for all new capstone cohorts due to its success.

INTERVENTION 2 (DO): A presentation designed to offer beneficial self-and-peer assessment recommendations was created by one of the faculty members. Former Capstone students' self-and-peer assessment written comments were utilized as illustrative examples to demonstrate what constituted helpful and less helpful recommendations based on the CATME dimensions. A specific framework for helpful recommendations, encompassing the attributes of being constructive, specific, measurable, sensitive, and balanced, was introduced and elaborated upon. The presentation was delivered by an expert one week before the Gate 1 report deadline. It is essential to note that the presentation took place at the beginning of a regular class in a theater-style classroom early in the morning. Students sit with their team members, scattering in the big classroom. As soon as the faculty started delivering the presentation, the students paid close attention to the speaker, a feeling the faculty did not expect as this was a big class with more than 100 students attending that particular class. Additionally, students engaged in the presentation by answering the faculty's questions regarding their CATME and team project experiences.

The presentation slides were also made accessible to students through the course site. For Gates 2-6, the lead instructor reiterated the presentation one week before the self-assessment and peer-assessment assignments deadlines.

IMPACT (CHECK): The intervention markedly improved the quality of self-and-peer assessment written feedback by Gate 1. Firstly, the participation rate in providing peer feedback approached 100%. Secondly, over 90% of students articulated their self-and-assessment written feedback in complete sentences that highlighted positive aspects and areas needing improvement based on the CATME dimensions, showcasing a significant enhancement in feedback quality.

Through these interventions, a pragmatic and positive step forward was achieved in addressing the challenges faced, leading to an improved educational experience for students amidst the unforeseen disruptions caused by the pandemic.

Interventions 2021-22

The presentation designed to offer beneficial self-and-peer assessment written feedback proved to be very successful. The instructors planned to continue working on how to have students reflect on their self-and-peer assessment comments. Here is an enhanced account of these observations and the subsequent actions that were undertaken:

OBSERVATION 1 (ACT-PLAN): Once the CATME results are released to the students, the faculty wanted to know if students reviewed their comments.

INTERVENTION 1 (DO): Once the CATME results are released, the students are required to review their results and write reflections on the following questions.

1. How did you feel about the written feedback provided by your peers?

2. Did your peers provide you with feedback that you can use to improve your performance on the team project?
   - If so, please provide an example.
   - If not, what would you like to see in the peer feedback?
3. How did you feel about providing written feedback to your peers? What went through your mind when writing the peer feedback?
4. The CATME rubric has five dimensions (Contributing to Teams Work; Interacting with Teammates; Keeping the Team on Track; Expecting Quality; and Having Related Knowledge Skills and Abilities). What dimensions did you focus on when writing peer feedback? And, why?

IMPACT (CHECK): Firstly, the student reflection assignment completion rate have been over 90%. Secondly, the quality and the quantity of the reflections has been significant (Huang et al., 2022a). Overwhelmingly, students indicated in their reflections that CATME self-and-peer assessment feedback was positive and helpful in improving team performance and dynamics.

Current Capstone Structure

The previous interventions have changed the structure and delivery of capstone education in the SoET, for the better. The present Stage/Gate framework spans across both capstone courses, featuring a total of 10 gates. This process is designed to structure and evaluate the progress of capstone projects through a series of checkpoints. Each gate serves as a milestone requiring specific deliverables, live bench demonstrations, written reports, oral presentations, and video presentations, culminating in the Tech Expo.

The Stage/Gate process is now iterative and cumulative, meaning that each gate builds upon the work and feedback of the previous ones. The process emphasizes not only the technical progression of the project but also the ability to communicate effectively about the project's development, challenges, and outcomes.

Below we summarize the current structure of the two-course sequence.

First Course

Gate 1: Initiation

- Deliverables: Live bench demo and a written report.
- Objective: Introduce the project, goals, initial research, and preliminary design concepts.

Gate 1.5: Concept Validation

- Deliverables: Live bench demo and a formal oral presentation.
- Objective: Present refined project concepts based on initial feedback and further research.

Gate 2: Design Phase I

- Deliverables: Live bench demo and a written report.
- Objective: Showcase the development of the design, including prototypes and testing plans.

Gate 2.5: Design Review

- Deliverables: Live bench demo with a formal oral presentation.
- Objective: Review the design details, prototypes, and initial test results. Gather feedback for improvement.

Gate 3: Design Phase II

- Deliverables: Live bench demo and a written report.
- Objective: Present advanced prototypes, comprehensive testing results, and iterations based on previous feedback.

Second Course

Gate 4: Build Phase I

- Deliverables: Live bench demo and a written report.
- Objective: Demonstrate the current state of the product, including results from extensive testing and refinement.

Gate 4.5: Progress Presentation

- Deliverables: Live bench demo with a video presentation.
- Objective: Highlight progress, current results, and planned steps toward finalization.

Gate 5: Build Phase II

- Deliverables: Live bench demo and a written report.
- Objective: Showcase the near-final product, comprehensive testing results, project outcomes, and reflections on the process.

Gate 5.5: Final Review Preparation

- Deliverables: Live bench demo with a video presentation.
- Objective: Present the project's progress, challenges, solutions, and the path to the final presentation. Focus on storytelling and impact.

Gate 6: Project Closure

- Deliverables: Tech Expo and a written report.
- Objective: Deliver a concluding report detailing the project from initiation to completion, including lessons learned, project documentation, and recommendations for future work.

FUTURE DIRECTIONS & REFLECTIONS

Starting in 2016, a remarkable evolution has been observed in capstone education within the SoET. Interventions were developed and deployed with the aim of enhancing the student learning experience.

During the Foundations phase (2016-2018), the need for change was recognized by the instructors through reviews of assessment data and personal observations. It was determined from assessment data that students were facing challenges related to the timing of their work completion. Written comments from students also expressed concerns regarding project timing and the completion of assigned tasks (Lucietto, & Berry, 2017; Lucietto et al., 2017a; Lucietto et al., 2018). Furthermore, the instructor's personal observations corroborated these assessment findings.

The primary focus during this period was on the development of interventions designed to assist students in managing their work timing and organizing resources effectively. The structured Learning Management System (LMS) and Library Course Site were implemented for students engaged in their capstone projects (Phillips & Huber, 2022). Additionally, measures were taken to restructure the capstone course, as outlined in Table 8, in order to provide students with more time to dedicate to their capstone projects.

During the Implementation and Impact phase (2018-2021), interventions were developed to improve teamwork and project quality. By examining peer evaluation data and the relationships to the peer ratings with additional questions (Beigpourian et al., 2019;Meulbroek et al., 2019), it was determined that interventions were required to instruct students on how to provide constructive feedback (Berry et al., 2022; Huang et al., 2022b).

In addition, with the implementation of iterative writing assignments, significant progress has been observed in the capstone teams' projects from initiation to completion, as evidenced by their Gate reports and presentations (Berry et al., 2018; Berry et al., 2021b;Lucietto et al., 2017b Furthermore, their information literacy has demonstrated improvement in relation to their projects (Phillips et al., 2020).

In the Future Directions phase (2021 and beyond), the challenges posed by COVID-19 provided instructors with opportunities to experiment with and adapt new instructional models for student engagement. Consequently, in the 2021-22 academic year, the initiation of a transition from a lecture-lab teaching model to a studio learning model was observed. This model was characterized by a reduced emphasis on lectures and a heightened focus on team-oriented learning experiences.

In 2022-23, the implementation of studio learning commenced, with instructors assuming the roles of coaches/facilitators, guiding teams through their projects while serving as valuable resources when required. The design of the studio learning model placed the responsibility for learning squarely on the students. All course activities were either designed or redesigned to progressively integrate content knowledge acquisition through a stage/gate framework, with the completion of Gates 1-3 occurring in the first course and Gates 4-6 being addressed in the second course, ultimately leading to the final deliverable. Furthermore, including the CATME reflection in 2022-23 allowed students to read and respond to the peer feedback they received. Instructors initially harbored apprehensions about how students would respond to this addition, but the experience has proven to be very positive.

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