Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025 ASEE
Paper ID #47726

Developing an Entrepreneurial Mindset by Bridging Design and Construction – Incorporating Three Cs in Civil Engineering Technology Courses

Dr. Amanda Y Bao P.E., Rochester Institute of Technology

Amanda Bao is a Professor and Interim Chair in the Department of Civil Engineering Technology, Environmental Management and Safety at Rochester Institute of Technology (RIT). She got her Ph.D. degree in Civil Engineering from the University of Colorado at Boulder, USA, in 2006. Dr. Bao started teaching at RIT in 2010 and she regularly teaches structural engineering courses. Prior to RIT, she worked as a bridge structural engineer at Jacobs Engineering Group, Inc. and Michael Baker International, Inc. in Denver, and she is a licensed professional engineer in Colorado and New York, USA. Dr. Amanda Bao won the 2021 Eisenhart Award for Outstanding Teaching at RIT. Dr. Bao has been actively involved in engineering education research since 2011, including digital learning, active learning and intensive collaboration with industry. Dr. Bao develops a teaching website: http://baoteachingcet.com/ and opens a YouTube Structural Design Teaching channel to post screencasts to supplement traditional lecture-type classes, and she also created hands-on active learning modules to improve teaching and learning effectiveness. In addition to education research, Dr. Bao conducts research in the areas of bridge resiliency and sustainability, innovative construction materials and evaluation of aging infrastructure. She has extensive research experience in finite element modeling and lab testing of structures and published more than 30 research papers. She is an active member in ASEE, ASCE and AISC.

Dr. Yewande S Abraham, Rochester Institute of Technology

Yewande Abraham Ph.D., LEED AP O+M, is an Assistant Professor in the Department of Civil Engineering Technology Environmental Management and Safety at Rochester Institute of Technology (RIT). She received her Bachelor's and Master's in Civil Engineering from Cardiff University, Wales.

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Amanda Bao[1, *] and Yewande Abraham[2]

[1]: Professor, Department of Civil Engineering Technology, Environmental Management and Safety, Rochester Institute of Technology, Rochester, NY, USA

[2]: Associate Professor, Department of Civil Engineering Technology, Environmental Management and Safety, Rochester Institute of Technology, Rochester, NY, USA

[*]: Corresponding author, Email: axbite@rit.edu

Abstract

The three Cs of an entrepreneurial mindset- curiosity, connections, and creating value- enable civil engineers to positively impact the built environment and create value for clients and key stakeholders to meet societal demands. This study focused on developing new course materials for two civil engineering technology technical elective courses, "Design of Highway Bridges" and "Construction Planning, Scheduling, and Control," to incorporate the entrepreneurial mindset and reinforce the application of the three Cs in the civil engineering industry. The connection between different components of the design and construction phases was emphasized in both courses to promote students' whole-system awareness. The updated course materials included recorded interviews with civil engineering design and construction professionals, case studies, lecture content, and targeted assignments. These materials were designed to emphasize the critical role of collaboration between design and construction professionals in developing optimal solutions. Student feedback on the learning outcomes related to the three Cs, the value of incorporating case studies in the curriculum, and the application of an entrepreneurial mindset in design and construction was gathered through a survey administered at the end of the semester. The results indicated that students were able to apply the entrepreneurial mindset through the new learning materials, improve their understanding of the connection between design and construction, and enhance their ability to communicate valuable design solutions to foster collaboration. This study provides valuable insights and facilitates further implementation of the entrepreneurial mindset in broader civil engineering and construction courses.

Keywords: entrepreneurial mindset, civil engineering, case study

1. Introduction

In recent years, efforts have been directed at the inclusion of the entrepreneurial mindset in engineering curricula. This increasing interest reflects a growing belief in the need for engineers to have, besides technical skills, an entrepreneurial mindset that leads to enhanced innovative competence, flexibility towards market dynamics, and value creation in their professional work [1]. An entrepreneurial mindset incorporates attitudes, beliefs, and thought processes that influence motivation to involve the future engineering workforce in opportunities to increase curiosity, make connections, and create value – the three Cs [2]. As such, Entrepreneurially Minded Learning (EML) guides students in managing challenges, seizing opportunities, and increasing their impact. Some other attributes of the entrepreneurial mindset include resiliency, risk-taking, creativity, collaboration, communication, vision, and adaptability [3]. The entrepreneurial mindset is less about specific skills and more about a holistic approach to problem-solving, opportunity recognition, and creating value. The Kern Entrepreneurial Engineering Network (KEEN) framework serves as a guide to incorporating EML into engineering curriculum [2].

Civil engineers play a crucial role in shaping and advancing the built environment. They work with various stakeholders, including clients, end users, suppliers, designers, contractors, and other project team members. The civil engineering body of knowledge identifies four categories (foundational, engineering fundamentals, technical, and professional), including 21 outcomes for civil engineers to acquire [4]. Many of these outcomes are addressed through the KEEN framework. Integrating an entrepreneurial mindset into civil engineering education fosters a culture of critical thinking and collaboration, enabling civil engineers to approach challenges holistically by considering diverse stakeholders and environmental contexts [5]. This broadened awareness enhances problem-solving capabilities while empowering professionals to create innovative, sustainable, and value-driven solutions that address societal needs and align with long-term goals [6].

This study shares findings from the incorporation of KEEN student learning outcomes in two undergraduate technical electives, “CVET 434- Design of Highway Bridges” and “CVET 464- Construction Planning, Scheduling, and Control” in a civil engineering technology program. The new course materials integrated the three Cs—curiosity, connections, and creating value—into the curriculum to ensure students develop the skills and mindset to create value for society.

2. Background

The potential of civil engineers to add value extends well beyond traditional design and construction practices. Society is increasingly calling on civil engineers to solve some of the most current, often complex, problems surrounding issues such as urbanization, climate change, and infrastructure sustainability [7]. By incorporating innovative approaches and new technologies, civil engineers can improve the functionality, resilience, and sustainability of infrastructure, contributing to a higher quality of life for the community [8]. Value creation by civil engineers in design and construction continues to be dominated by sustainable practices. Current practices have proved that sustainable infrastructure contributes not only environmental benefits but also brings economic advantages regarding reduced operational costs and increased property value [9].

Aspiring civil engineers should be able to make connections between design and construction and foster collaboration for successful project delivery [10]. They also have to balance meeting technical requirements with considerations of ethical and social responsibilities. In addition, new technologies such as smart materials, artificial intelligence (AI), and data analytics present new opportunities for civil engineers to add greater value to the built environment. These tools, technologies, and techniques allow the management of projects to be more efficient, while the stakeholders can also collaborate and make decisions more effectively [10]. Civil engineers need to work out optimal designs that minimize waste and ensure better performance of infrastructure [11]. As the industry continues to evolve, it becomes requisite that civil engineers adopt these innovations while incorporating an entrepreneurial mindset into their practices to remain relevant and offer the services needed for the evolving needs of society.

Civil engineering educators can incorporate EML into courses to guide students in solving difficult challenges within the built environment. Welker et al. [5] presented several examples of how EML was incorporated into several civil engineering courses at a higher education institution. An entrepreneurial mindset encourages individuals to become more aware of connections and they are better able to apply problem-solving skills through curiosity. They do not only think of the immediate solution but the long-term consequences of their decisions and actions. Encouraging the entrepreneurial mindset can stimulate students to analyze problems holistically, considering different stakeholders and the impacts of their decisions [6]. This holistic approach improves problem-solving skills and prepares students to develop sustainable solutions that will be useful for many parties.

Introducing EML using inductive learning approaches (for example, through projects and real-life case studies) provides hands-on learning experiences to enhance student participation and promote deeper learning [12]. Active learning approaches can lead to improved performance, increased interest, and engagement among students in civil engineering [14], [15].

3. Research Methodology

This project aims to engage upper-level civil engineering students in EML through two technical elective courses “CVET-434 Design of Highway Bridges” and “CVET-464 Construction Planning, Scheduling and Control.” These two courses were selected since one was focused on design and the other on the construction aspects of projects. CVET-434 course materials are focused on bridge design theories, analysis, and structural member design, with minimum exposure to bridge construction. Most students who enrolled in CVET-434 are interested in careers in structural or transportation engineering, specifically in design and consulting firms, after graduation. On the other hand, CVET-464 is focused on construction planning and the development of schedules to improve efficiency and productivity on construction projects. Most students who enrolled in CVET-464 are interested in construction management careers. It is important for construction managers to understand the design aspects, and for design engineers to understand the construction process for a smooth project delivery. EML content was newly introduced in CVET-434, whereas in previous offerings of CVET-464, it had been briefly incorporated. In addition, the connection between design and construction was emphasized in

both courses to promote students' whole-system awareness. The research approach is presented in Figure 1.

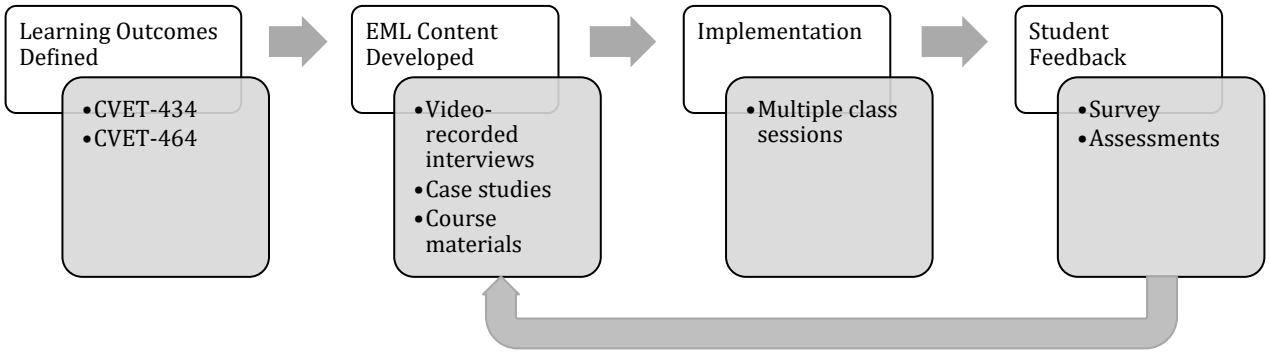


Figure 1. Research Approach

The semester the study was conducted, the number of students who enrolled in both courses in 2024 and the survey response rates are provided in Table 1. Both courses were taught in person.

Table 1. Course Enrollment and Survey Responses

Course	Semester Offered	Enrollment	Response Rate (%)
CVET 434	Spring 2024	12*	100
CVET 464	Fall 2024	17	100

*11 officially enrolled and 1 audited the course

For both courses, the expected learning outcomes for an entrepreneurial mindset were defined and are listed below:

1) Identify opportunities to create value by assessing a variety of design and construction planning solutions.
2) Assess the connections among key stakeholders in civil engineering project design and construction phases to foster collaboration and community engagement.
3) Apply EML and sustainable design concepts through real-world case studies.
4) Develop and communicate valuable engineering solutions to foster collaboration and community engagement.
5) Compare different engineering solutions and learn from success stories as well as failures.

EML content was developed for each of the courses to address the learning outcomes. The new course materials included recorded interviews with civil engineering design and construction professionals, case studies, lecture materials, and assignments aimed at addressing the importance of collaboration between design and construction professionals to create the best solution. The materials developed include video-recorded interviews of six civil engineering/construction industry professionals to gather their input on EML and the connection between design and construction. The professionals were presented with the KEEN framework

and given the opportunity to select the questions they felt confident in addressing (Table 2). The recorded videos were edited and captioned as one instructional video used in both courses.

Table 2. Interview Questions

Question #	Description
1	Can you describe the connection between various stakeholders (related to design and construction) in the civil engineering/construction industry?
2	What do you believe are the critical factors for success in projects considering the connection between the design and construction phases?
3	How do you think the entrepreneurial mindset (curiosity, connection, and creating value) can benefit design and construction projects?
4	Can you provide an example of an instance where an entrepreneurial mindset (curiosity, connection, and creating value) led to innovative solutions in design and construction?
5	In your opinion, what are the key milestones and timelines to consider when developing construction schedules for projects?
6	How important is sustainability consideration in the planning and execution of civil engineering projects (e.g., bridges, buildings) design and construction?
7	What role do key stakeholders, including the design and construction team, play in the creation and implementation of a construction schedule?
8	Could you share any specific challenges you've encountered in managing construction schedules for complex projects?
9	How do you see the incorporation of case studies into the curriculum benefiting future civil engineering and construction professionals?

Case studies were implemented in the courses to give students application-based real-world learning experiences and help them connect theoretical concepts to practical applications. The case studies implemented in CVET-434 included a design-build project in Las Vegas, Nevada "Sunset Road Bridge over I-15" explaining the connections between design and construction in the project delivery, and an award-winning bridge in Rochester, New York "I-390 over I-490" for optimizing design, construction, and maintenance, as demonstrated in Figure 2.

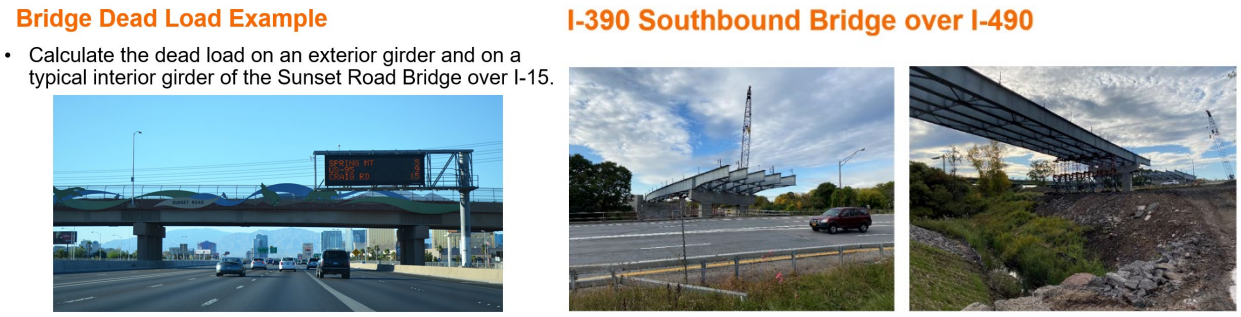


Figure 2. Sample Case Studies in CVET-434

The lecture materials included content to introduce the 3Cs and other content specific to each course (Table 3). This content was implemented in multiple course sessions. At the end of the semester, students enrolled in each of the courses voluntarily participated in paper-based surveys to provide feedback on the learning outcomes related to EML on a five-point Likert scale, 1

being the lowest and 5 being the highest. They also responded to two open-ended questions regarding the importance of case studies and how they think the entrepreneurial mindset can impact design and construction projects. The responses were analyzed using Microsoft Excel to calculate the mean scores for each statement on the Likert scale. Open-ended responses underwent thematic and content analysis to identify key patterns. Additional feedback was also gathered through the assessment of student submissions. The findings from student feedback will inform future improvements in course delivery and curriculum development.

Table 3. Sample Course Materials Developed

CVET-434	CVET-464
New course materials about bridge type selection were implemented. The connection between the bridge type selection and construction methods was emphasized, and a new exam problem was introduced to assess the students' knowledge.	New course materials for collaborative construction schedule development was introduced. Students were assessed on their implementation of the 3Cs in their final project on developing a schedule for the reconstruction of a fire station.
A new lecture on the rationale of design for construction and inspection was delivered to address the importance of cooperation between design and construction to create the best solution. A new homework assignment problem about design for construction and inspection was incorporated.	A case study on the importance of collaboration between design and construction teams and the involvement of key stakeholders in the construction process was incorporated through role play. The case study was analyzed through class discussions.

4. Results

The survey questions and the mean ratings of EML-related learning outcomes for CVET-434 and CVET-464 are listed in Tables 4 and 5, respectively. The survey was first implemented in CVET-434 in the spring of 2024 and improved in the fall of 2024 for CVET-464. In most cases, students highly ranked their ability to perform activities related to EML-related learning outcomes.

Students in the design-based course (CVET-434) rated their ability to effectively propose and communicate solutions that encourage collaboration between design and construction teams higher than students in the construction-based course (CVET-464). CVET 434 students also rated their ability to identify opportunities to enhance value by analyzing design and construction solutions, learning from both successes and failures higher than CVET 464 students. Additionally, students in CVET 464 reported that they recognized the value of cooperation and collaboration between design and construction teams in delivering value to clients and end users with a mean score of 4.82 on a 5-point Likert scale.

For the statement on developing the ability to engage key stakeholders in construction projects to promote collaboration and foster community engagement, both groups of students rated this the lowest. CVET-434 students rated this statement 3.5 while CVET-464 students rated this 3.94.

Table 4. CVET-434 Mean Rating of EML-related Learning Outcomes

EML-related Learning Outcome	Mean Rating
Understand the connection between design and construction and consider design for construction and inspection in the bridge industry to address the importance of cooperation between design and construction to create the best solution.	4.33/5
Identify opportunities to create value by assessing different bridge design and construction planning solutions while learning from success stories as well as failures. (For example, bridge type selection, construction time, road closure, etc.)	4.25/5
Assess the connections among key stakeholders in bridge project design and construction phases to foster collaboration and community engagement.	3.5/5
Communicate valuable bridge design solutions to foster collaboration between design and construction.	4.42/5
Compare different bridge design solutions and learn from success stories as well as failures.	4.0/5

Table 5. CVET-464 Mean Rating of EML-related Learning Outcomes

EML-related Learning Outcome	Mean Rating
I have a stronger understanding of the relationship between design and construction and the importance of adhering to and verifying design requirements during construction.	4.35/5
I recognize the value of cooperation and collaboration between design and construction teams in delivering value to clients and end users.	4.82/5
I am able to identify opportunities to enhance value by analyzing design and construction solutions, learning from both successes and failures.	4.06/5
I have developed the ability to engage key stakeholders in construction projects to promote collaboration and foster community engagement.	3.94/5
I can effectively propose and communicate solutions that encourage collaboration between design and construction teams.	4.24/5

In addition to the Likert scale ratings, students also provided open-ended responses to the following questions:

1) How do you see the incorporation of case studies into the curriculum benefiting future civil engineering and construction professionals?
2) How do you think the entrepreneurial mindset (curiosity, connections, and creating value) can benefit design and construction projects?

The responses of CVET-434 students to the first question regarding the benefits of incorporating case studies in civil engineering education include these key themes: real-world application and learning from experience, avoiding failures and improving designs, bridging theory and practice, and enhancing critical thinking and visualization. One of the student responses mentioned this *"Real life case studies are important for visualization and putting all the theory learned in perspective."* Another student mentioned, "*A good way to see theories vs. practice.*"

For CVET 464 students, the key themes also included bridging the gap between theory and practice, enhancing critical thinking and problem-solving skills, providing reliable and valid learning experiences, and learning from successes and failures. One student mentioned, *"I think they are very important as they show where success and failure have happened and how you can build from it with your own scheduling in the future,"* Another student mentioned, *"They show real examples for students to remember in the field."*

The word cloud in Figure 3(a) from CVET-434 students featured the following most used words: "*real*," "*failure*," "*case studies*," "*bridge*," and "*design*" suggesting learning from real-world case studies and past failures for better bridge design. The word cloud in Figure 3(b) from CVET-464 students included the most used words: "*real*," "*example*," "*project*," "*future*," and "*case studies*" indicating an emphasis on practical, hands-on learning and preparation for the professional field.

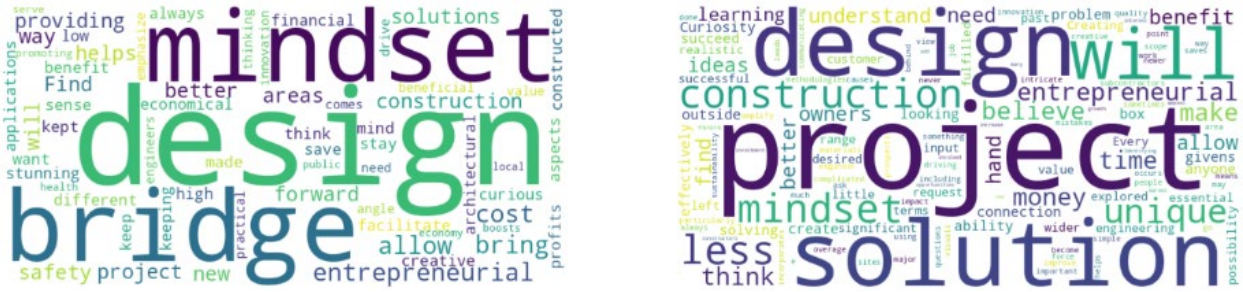
(a)Word Cloud for CVET-434 (b) Word Cloud for CVET-464

Figure 3. Responses to how the Incorporation of Case Studies into the Curriculum can Benefit Future Civil Engineering and Construction Professionals

CVET-434 students view case studies as a tool for learning from past structural failures and improving engineering design. CVET-464 students value case studies as a way to bridge classroom learning with real-world construction experiences. Both groups agree that case studies enhance engagement, visualization, critical thinking, and professional preparedness.

The responses of CVET-434 students to how the entrepreneurial mindset (curiosity, connections, and creating value) can benefit design and construction projects show the following themes: cost efficiency, innovation and creativity, and safety and practicality. Some of their responses are presented here: "*The mindset helps in different ways. To stay curious and always want to do better design*," "*I think the entrepreneurial mindset helps to keep costs low and profits high while also keeping in mind safety of design*," and "*We need to emphasize the value we are providing with these projects and how promoting the health and safety of public boosts the local economy for the areas that these bridges serve*." The CVET 464 responses focus on themes such as creativity and problem-solving, expanding possibilities, balancing time, money, and quality, sustainability and innovation, and collaboration among stakeholders. Some of their responses are presented here: "*Entrepreneurial mindset will allow for a wider range of solutions and methodologies in construction and design,*" "*I think it can improve projects in the area of money, time, and quality*," and "*I believe it can be or should be the driving force behind the projects, sustainability and innovation go hand in hand with this mindset, I believe they amplify each other.*"

The word cloud for CVET 434 shows the prominent words: *mindset, design, and bridge* (Figure 4a). This suggests that responses in this group focused on applying an entrepreneurial mindset to bridge design, cost efficiency, and problem-solving. The word cloud for CVET 464 shows the prominent terms: *project, solution, design, construction, mindset, and unique* (Figure 4b). This group emphasizes a broader project-oriented perspective, considering customer satisfaction, problem-solving, and innovation.



(a)Word Cloud for CVET-434 (b) Word Cloud for CVET-464

Figure 4. Responses to How EML can Benefit Design and Construction Projects

Both groups recognize the entrepreneurial mindset as a tool for fostering innovation in design and construction. They mentioned cost efficiency and financial considerations, and improved design solutions as other benefits of the entrepreneurial mindset.

In addition to the surveys, the EML outcomes were assessed by students' performance in the homework assignment and the exam problem on the connection between bridge design and construction in CVET-434. The assessment showed all students achieved a score of 80% and over in the EML-related problems. For CVET-464, students were able to connect the design and construction aspects of their final projects and describe opportunities to create value for the project stakeholders, including the client, project team, and community.

5. Discussion

This study demonstrates the value of integrating EML into civil engineering education through its focus on curiosity, connections, and creating value. By embedding these principles into two civil engineering technology technical elective courses, students gained essential skills that prepared them to enter the engineering workforce.

The feedback collected from paper-based Likert scale surveys revealed that students in both courses successfully engaged with EML-related outcomes. The EML-related learning outcome on "developing the ability to engage key stakeholders in construction projects to promote collaboration and foster community engagement" was rated the lowest by both groups of students. For the case study used in CVET 464, the instructor did not have enough time to allocate for the role play. In the future, course content increasing student awareness of stakeholder roles could be incorporated into future course offerings ensuring there is enough time for the case study analysis and role play. This could be approached through stakeholder mapping activities, case studies of real-world construction projects, and interactive role-playing

activities that simulate stakeholder negotiations. Additionally, guest lectures from industry professionals and community leaders could provide practical insights into stakeholder engagement. Integrating these elements would help students develop a deeper understanding of the complexities involved in balancing diverse interests, ultimately strengthening their ability to foster collaboration and community engagement in construction projects.

The open-ended responses further highlighted the benefits of incorporating real-world case studies and an entrepreneurial mindset into the curriculum. Students mentioned the importance of case studies as a pedagogical tool, highlighting their ability to bridge theoretical knowledge with practical application. They noted that an entrepreneurial mindset improves project outcomes by enhancing time management, cost efficiency, design quality, and sustainability while encouraging collaboration through diverse perspectives and better communication. They emphasized that it fosters thinking beyond conventional approaches, enabling more intricate designs, learning from mistakes, and creating opportunities for professional growth. Students recognized the potential for EML to promote innovation, cost-effectiveness, and sustainability in civil engineering projects. CVET-434 students emphasized its role in developing creative and impactful bridge designs, while CVET-464 students highlighted the benefits related to improving project outcomes through better time management, design quality, and stakeholder engagement.

Moreover, students linked the entrepreneurial mindset to professional growth, suggesting that curiosity, connections, and value creation foster lifelong learning and skill development. While students in both courses recognized the importance of the entrepreneurial mindset, its practical application in professional settings may require deeper engagement with industry stakeholders, as noted by students' desire for more real-world exposure. Furthermore, students expressed a desire for more opportunities to interact directly with industry professionals, highlighting the need to further bridge the gap between academia and real-world practice.

6. Conclusion

The findings of this study support the integration of EML into civil engineering/engineering technology education. By emphasizing curiosity, connections, and creating value, the modifications made to the curricula enhanced collaboration, critical thinking, whole system awareness, and problem-solving. These attributes are critical for addressing modern challenges in the engineering profession, such as sustainability, urbanization, and resource efficiency. Students' feedback indicated that the revised course content facilitated the development of an entrepreneurial mindset, equipping them with the tools necessary to navigate the complexities of the built environment.

The incorporation of real-world case studies proved to be an effective pedagogical tool, reinforcing student engagement, critical thinking, and professional preparedness. This aligns with research on inductive learning, which emphasizes the role of case studies in connecting theory with practice. Students highlighted that EML not only improves project outcomes—by enhancing time management, cost efficiency, and design quality—but also fosters innovation, collaboration, and stakeholder engagement. Additionally, students linked the entrepreneurial mindset to professional growth, emphasizing that curiosity and value creation foster lifelong learning and skill development.

Meanwhile, this study identified some limitations. One of the primary challenges was the small sample size due to the technical elective enrollment, which affected the generalizability of the findings and limits the ability to conduct subgroup analyses (e.g., examining differences in learning outcomes based on demographics or prior experience). The subjectivity of survey responses and the lack of baseline data on students' prior knowledge of EML also presented additional limitations.

To enhance the integration of EML in civil engineering education, future efforts should focus on expanding opportunities for direct engagement with industry professionals. This could include guest lectures, stakeholder mapping exercises, and interactive role-playing activities that simulate real-world negotiations in construction projects. Additionally, incorporating more hands-on, experiential learning opportunities—such as co-op placements or interdisciplinary collaborations—could further strengthen students' ability to apply the entrepreneurial mindset in professional settings. By continuing to refine and expand EML-based curriculum enhancements, educators can better prepare students to develop innovative, sustainable, and value-driven solutions that meet the evolving demands of the civil engineering and construction industries.

7. Acknowledgments

This project was supported by the KEEN EML Teaching & Learning (KETL) Grant program at Rochester Institute of Technology. The authors also extend their appreciation to the civil engineering design and construction professionals who contributed their insights and expertise through recorded interviews, the students who participated in this study for their valuable feedback, and the graduate assistant, Emmanuel Achema, who contributed to the data pre-processing.

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