Applications of Teams and Stories: Augmenting the Development of Entrepreneurial Mindset in Engineers

Dr. Ellen Zerbe, Georgia Institute of Technology
Dr. Adjo A. Amekudzi-Kennedy, Georgia Institute of Technology

Professor Adjo Amekudzi-Kennedyâ€™s research, teaching and professional activities focus on civil infrastructure decision making to promote sustainable development. She studies complex real-world systems and develops infrastructure decision support system

Dr. Kevin Haas, Georgia Institute of Technology

Associate Chair of Undergraduate Programs, School of Civil and Environmental Engineering

Dr. Robert Benjamin Simon, Georgia Institute of Technology

Robert Simon serves as an Academic Professional for the School of Civil and Environmental Engineering (CEE) at Georgia Tech. He contributes to our undergraduate Global Engineering Leadership Minor, as well as our new Innovation & Entrepreneurship track, by infusing leadership, innovation, and team effectiveness into our engineering curriculum. He co-instructs our Innovation & Entrepreneurship in CEE Systems course, and is a member of the instructional team for several CEE undergraduate courses.

Ms. Janece Shaffer

Janece Shaffer, award-winning playwright and founder of StoryReady, has teamed up with Georgia Techâ€™s Dr. Joseph Le Doux to create a signature storytelling curriculum that is now required for all biomedical engineering students. Shaffer is also currentl

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Abstract

Calls from the American Society of Civil Engineers and the National Academy of Engineering, and a similar but more recent statement from the National Association of Colleges and Employers all assert the need for engineers that are not only competent with a certain set of knowledge and skills, but also have a mindset for creating value. In order to accomplish this, engineering content needs to not only engage the students cognitively but also in the affective domain, fostering students' identity as engineers who have an entrepreneurial mindset. We present two accounts of how story-driven learning and focused team development were integrated into different courses and highlight how they can amplify the impacts of activities fostering curiosity, connections, and value creation (the 3Cs), which nurture entrepreneurial mindset. In one, this results in students who have more clarity regarding their own engineering identity and the unique perspectives their peers can contribute. In the other, students learned and applied principles of effective teaming and used stories to reflect on their experiences. Student reflections, individually and in teams, show augmented self-awareness, appreciation of trust and stronger connections as keys to stronger teams, and an association of stronger teams with better teamwork, affecting project outcomes. Their reflections highlight how teams and stories may be used together to augment student connections and project outcomes, adding value both to the learning experience and outcomes, and, in so doing, to future academic and professional project experiences. Ultimately this creates students who are more self-aware and proficient in collaboration, identify more deeply with the profession, and can integrate the 3Cs into their work.

Introduction and Literature Review

Typically, higher education is centered around the cognitive domain, i.e., the development of knowledge and skills. Bloom's taxonomy is classically used as a way to categorize learning behaviors by increasing complexity [1]. But beyond the cognitive, Bloom and his colleagues also categorized learning in the affective domain and asserted that learning in the one domain was integrated with learning in the other [2]. The affective domain is often mistaken to be limited to only dealing with emotions, but rather, it represents how a student internalizes information and how it contributes to their attitudes and motivations. Similar to how the cognitive domain is subdivided, the authors divide the affective domain by types of behaviors: receiving, responding, valuing, organizing, and characterizing. The subdomains of the cognitive domain are more straightforward to quantify than those of the affective domain. Learning in the affective domain is often not incorporated into educational objectives and evaluations, despite studies in neuroscience and education demonstrating its effectiveness in supporting cognitive learning outcomes [3], [4] and professional and disciplinary identity development [5], [6].

There is a growing body of knowledge that to create effective engineers, students need to not only be proficient in engineering knowledge and skills, but also need to engage in the affective domain as well [7]–[11]. Specifically in civil engineering, work has been done to reconcile the affective domain with cognitive domain. ASCE's Body of Knowledge outlines the general

knowledge that all civil engineers should have. The outcomes of this report are predominantly based in the cognitive domain, but work has been done to align those knowledge outcomes with outcomes in the affective domain, both for the second edition [12]–[14] and the third edition [15].

Education that integrates cognitive and affective outcomes is often referred to as holistic education [11]. There is recognition of the need to educate holistic engineers, that is, engineers that leverage cognitive, interpersonal, and intrapersonal skills [16], [17]. In 2006, ASCE's *Vision of Civil Engineering in 2025* (2006) outlined the need for future engineers to be knowledgeable in engineering fundamentals, skilled in ways that support future learning and teamwork, and hold attitudes that are necessary in the profession. Holistic education, and engagement in the affective domain, is a way to develop those attitudes. Not long after the publication of ASCE's vision, the National Academy of Engineering published a call to action to address societal grand challenges (2008), and required engineers to be competent not only in engineering knowledge, but also in problem-solving and interpersonal skills in order to address the challenges. Yet even as we approach the 2025 benchmark, we are still looking to improve the development of skills beyond the cognitive in our engineers. While extending outside engineering, the results of two Job Outlook reports show a decrease in reliance on GPA as a metric for student capabilities and increased interest in problem-solving and interpersonal skills [20], [21].

Entrepreneurial Mindset

The specific attitudes outlined in the *Vision of Civil Engineering in 2025* include creativity/entrepreneurship, commitment, curiosity, honesty/integrity, optimism, respect/tolerance, and thoroughness/self-discipline [18, p. 12]. While all are vital in professional practice, two of these are directly supported by the development of an Entrepreneurial Mindset (EM); creativity/entrepreneurship and curiosity. "Entrepreneurship" in both ASCE's report and when referring to EM development is not specifically about creating new start-up companies. Instead it refers to a developed habit to seek out opportunities to create value [22]. Developed and supported by the Kern Entrepreneurial Engineering Network, EM is comprised of three elements: curiosity, connections, and creating value (the 3Cs). The 3Cs work in tandem with an engineering skillset to create engineers who understand the impact of their design and pursue opportunities to "create extraordinary value" [23]. Value creation fits naturally in our current understanding of the purpose of an engineer. Although an entrepreneurial mindset and value creation might often be equated with economic and/or social value, creating value in this sense includes cultural and environmental values as well. A more recent report from ASCE reiterated this by emphasizing that civil engineering students need: the *skills* necessary to succeed in the profession; *authentic experiences* to promote learning; a *mindset* toward innovation, societal focus, sustainability and systems-thinking; a *commitment* to diversity, equity and inclusion; and the *flexibility* to pursue their passion [24]. Similarly, environmental engineering students need to: move towards *systems-based* solutions; become proactive in *anticipating problems*; and *cultivate diversity and engage collaboratively* with stakeholders and other disciplines [25]. By developing EM, we support engineering students' "mindset toward innovation" and help them learn how to "proactively anticipate problems." Many studies surrounding EM and Entrepreneurially Minded Learning

(EML) have been conducted regarding classroom and curricular interventions [26]–[29], mindset assessment [30]–[33], and alignment with ABET outcomes [34], [35].

Teamwork Development and Story-Driven Learning

Two approaches we have used to support EM development are focused teamwork development and story-driven learning (SDL). Included in many lists of skills necessary for successful engineers, like the reports previously cited, is the ability to collaborate and work effectively in teams. Leveraging teams in engineering courses is used as a model to prepare students for working in industry [36]–[38]. The ability to work in teams is also a learning outcome identified by ABET [39]. Beyond this, teams have been used to encourage innovation and creativity in engineering students [40], [41], supporting EML. By working in teams, students exercise their curiosity by exploring and understanding different perspectives, build connections between their ideas and those of their teammates, and can more effectively create value through a deeper understanding of how individual and community values shape the human experience. Despite its recognized importance [42], teamwork skills (and other inter- and intrapersonal skills) are often relegated to the realm of "soft skills," considered separate from "technical" engineering skills, and potentially neglected in favor of more "rigorous" content [43]. Similarly, the role that reflection and internalization play in skill and mindset development is often undervalued in engineering [44] despite engineering education's increasing study of their value [45]–[47]. SDL encourages students to engage in reflection on their past experiences, current learning process, and how those impact their future goals [48]. By using SDL, students can not only grow in their understanding of themselves as engineers, therefore solidifying engineering identity, but also build empathy and strengthen connections between students [49]. Beyond introspection, SDL has also been used to encourage students to recognize and navigate bias in designs [50].

We propose that using teamwork development and SDL together can not only support EM development in engineering students, but also help them to support one another, by creating opportunities for them to reflect collectively and strengthen their teams. In this paper, we outline innovations in two courses in the civil and environmental engineering curriculum where teaming and reflection are used together to further the goals of EML.

Methods

This paper unpacks two civil and environmental engineering courses at Georgia Institute of Technology, Exploring CEE and CE Systems, where team development and story-driven learning were used to support the course content. While the courses are distant in the curriculum, one is for first-year students and the other is traditionally taken by third-year students, a similar workshop about failure was delivered to both courses. All changes and results are from the fall 2022 semester. The authors of this paper include the course instructors, team development and story-driven learning experts, and a postdoctoral fellow who coordinated training on entrepreneurial mindset learning with these faculty.

Exploring CEE

Exploring Civil and Environmental Engineering is an introductory course for first year engineering students within the school of civil and environmental engineering (CEE). The purpose of the course is to help students learn more about the CEE field and to begin building their professional identity. The course is designed to be highly interactive for the students to enhance their sense of belonging within the School of CEE. The class meets one hour a week in a standard lecture format with approximately 60 students, and two hours a week in smaller studio sessions with 30 students each. The course is organized into four modules with each module consisting of a Learn, Do, and Reflect components. The students work in teams for each module completing a short team project related to the module topic. They also complete a self-reflection exercise at the end of each module as well as a culminating reflection at the end of the course. Of the 61 students in the fall 2022 cohort, 37 were civil engineering majors and 24 were environmental engineering majors.

Exploring CEE: Stories

There were multiple story-telling interventions throughout the course. During the first week, the instructor and TA shared their personal stories about how they ended up in college and started their personal career path. The students were then asked to share their personal stories within small groups about how they ended up at Georgia Tech. The small groups were self-selected of nearby peers and not organized teams. The class discussion focused on the purpose of story-telling as a method for helping engineers who not only know what it means to create value but also see themselves as engineers who act to create value. The discussion also focused on the elements of effective story-telling: containing a transformation, immersing the listener in the environment, including sticky details, and containing some sort of emotion component. The students then practiced with additional personal story-telling exercises within small groups.

In the second month of the course, a studio session run by an SDL expert was fully dedicated to story-telling. The session began with the students going “back in time” to talk about what they loved to do as children, including creating drawings of what an ideal invention or gift to their 10-year-old self would be. After discussing this in small groups and with the class, the students had to reflect on what the child (young them) would think about where they are now, e.g., what would they love about you being at this university? Then progressing to 10 years into the future, the students had to imagine a potential future for themselves. They had to pick a scenario and describe where they were and what they were doing. This again was done in small groups and then with the rest of the class. To help them see that there were many options and that their path was wide-open, they had to completely reset and tell a brand-new vision about another possible future. They had to reflect on how this kind of "big picture" thinking grounds them in this moment. Can it inspire them when things become challenging? They then had to answer the question: what is the best advice you in the future could offer you now as you are embarking on your career journey?

Exploring CEE: Teams

Teamwork was an integral part of the Exploring CEE course. Each of the four modules within the course had team-based projects. Random teams comprised of four students each were

created at the start of each "do" phase. New teams were formed in each module. The students had approximately ten days to work on the project with their team, done predominately during the two-hour studio time each week. Two of the projects culminated with 10-minute presentations and the other two with an eight-page technical report. After the completing the first group project, a faculty member specialized in team development held a session about "Creating an Authentic and Safe Team Culture" to introduce the students to more effective teaming strategies. During this session, two of the components of EM, curiosity and connections, were discussed with regard to how they can be expressed and developed in a team setting. After the completion of each group project, the students were asked to complete a survey regarding the perceived effectiveness of the team, level of engagement, and any conflicts and challenges the team encountered.

CE Systems

The Civil Engineering (CE) Systems Course aims to develop a sustainability mindset in civil and environmental engineering students through a study of CEE systems, sustainable development, and sustainability evaluation tools, as well as the research, evaluation and enhancement of the sustainability and performance of a large-scale built system. It is generally taken by third-year as well as second-year civil and environmental engineering students and is a required course in the curriculum. In the fall 2022 semester, 2/3 of the 97 students were civil engineering majors, which reflects the distribution of the School of CEE. The course is presented in four modules. The first module reviews historical, current, and future global and local trends that make sustainability thinking and practice essential for CEE systems development. Content includes sustainability in professional codes of ethics, and models and rating tools for sustainability, environmental impact, and social equity assessment. During this module, the 3Cs of EM are discussed and then referred back to throughout the semester. In the second module, the students study how to apply optimization, multiple criteria and uncertainty evaluation tools. In the third module, the students study and apply engineering economic decision analysis tools. In the fourth and final module, which occurs across the entire semester, the students research, evaluate and recommend changes to a large-scale system to enhance its sustainability and performance by applying the tools they have studied and skills and mindset they are developing in the course through a group project.

CE Systems: Stories

Story techniques to reflect on the past and imagine the future were also used in this course. The first assignment in the course is for students to create a video that contextualizes their experiences with the content of the course. Students record a three-minute video where they reflect on how they came to be a civil engineering or environmental engineering major (past), connect with their most important takeaways from a lecture on climate change and an article on the earth's planetary boundaries (present), and imagine how the course will help them achieve their goals beyond the course (future). The intent of this reflection is to help the students tie the reasons for their major selection with critical societal challenges and opportunities related to CEE.

Another opportunity for reflection comes in the form of a class reflection on the values underlying sustainable projects, and the norms arising out of those values. The students brainstorm

values they see as most salient based on their team's study of a project and their peers' project presentations. The students use the Values Hierarchy Tool (adapted from a Value Sensitive Design method [51]). In this activity, students move from the values of the stakeholders that interact with the system, connect those values into the norms of the society in which the system is situated, and translate those norms to the design requirements. Similarly, students can also start with known design requirements, project how those accommodate the norms of the society, and deduce which values are supported by those norms. By navigating up and down the hierarchy, students start to see how the design requirements are not arbitrary, but rather, should be manifestations of the values of those using the system. From this exercise, students are expected to develop their appreciation of the power for values to shape the built environment, and a knowledge of values that foster the development of sustainable systems. They are also expected to come away with a stronger appreciation of the importance and difficulty of including representative stakeholder views when making decisions on the built environment.

CE Systems: Teams

Early in the semester, the students are assigned project teams of five that they will work with throughout the semester. The teams are created by the course instructor and the team development expert, purposefully creating as equally diverse teams as possible. In this case, diverse teams means distributing students by major, year in program, gender, and international vs US citizen status. The first assignment associated with this team project is another video assignment about which civil systems the group is interested in studying. The teams must work together to identify three megaprojects (i.e. $1 billion or more) and collectively articulate why they are curious about their chosen projects. This assignment happens very early on in the course and is designed to get the students working in their groups, give them the opportunity to negotiate among themselves on their top three choices for a project, and allow them to practice making a case for the projects they desire most to research. Having to identify their own projects fosters their curiosity about large-scale CEE systems in the U.S. and around the world, the nature of these built systems and their connections to the society in which they are located, the economy and natural environment; and the value they create for the societies they serve.

Teams play a foundational role throughout the course as the integrated application of the material learned in the course occurs within the team. The students complete their semester-long project in a team, which provides the integrative experience in the course, and is allocated the largest grade percentage of any assignment. They must work together to evaluate and propose changes to the system to enhance its value from a sustainability viewpoint. The goal is for the students to learn how to work effectively within a team to create value through the recommendations they make to enhance the sustainability of their respective systems. Focused team instruction is given to the students via four, fifteen-minute workshops distributed across the semester. The series focuses on team structuring, psychological safety, assessing team health and feedback, and conflict management. Each of these sessions provide in-class exercises designed to facilitate the teams finding connections between each other and previous team experiences, igniting curiosity through socialization exercises, and ultimately beginning to create value through identification of their own teams' core values.

Teams and Stories Together: Learning From Failure

Additionally, each course had an opportunity at the end of the semester to fully entwine team development with SDL into one final reflective session for the class. In both cases, the session was facilitated through a framework of failure. In Exploring CEE, team development and SDL experts together facilitated a single session centered around perceptions of failure. Prior to the session, students were asked to define what success at their institution looks like. In the session, the anonymized responses were shared, and students were asked to stand up if they agreed with the definition. The activity illustrated an important connection between the students: many of their fears and aspirations were shared by others. The instructors continued by exploring where their goals came from, and the difference between mastery and performance goal-setting [52]. Ultimately, students were asked to reflect upon one of their own recent failures and the aftermath. The instructors shared strategies on how to craft impactful and memorable narratives (i.e., specificity, transformation and emotion). The instructors noted that failure is not the end of the story, that students have the choice of how they frame their stories, and where their narratives start and stop. Students were then invited to consider failure through a larger lens that would encourage them to recognize the value of the lessons learned. From a team dynamic standpoint, students reflected upon the importance of understanding how their team copes with failure (as opposed to them individually) if, and when it arises. For CE Systems, the same two instructors led a class-reflective discussion on the journey they experienced over the semester. Particular attention was paid to how much they overcame through the project, as a team and individually, and advice they would share with their first-day selves.

Results

The story-telling elements of Exploring CEE emphasized the student's sense of belonging within the school and the profession. One metric of the success of this outcome is to evaluate student retention within CEE. Historically, approximately 50% of the students who matriculate as first-year students in CEE end up changing their major before graduation. For this cohort of 60 students who took Exploring CEE in fall 2022, only five have changed their major. While this is still early since this cohort has completed the course, this is still a decrease rate of attrition from a similar point in previous years. In addition, their personal reflections at the end of each module allowed the students to articulate how the course and the associated activities were impacting the beginning of their academic journey. Even those students who did change their major felt that they were able to make an educated decision and felt like it was the correct change for their personal goals.

Three short surveys about team experiences were collected after the "Do" phases (i.e. the small group projects) of modules 1, 2, and 3. Figure 1 shows the distribution of responses to the questions "What was the level of engagement from all team members?" and "Rate how effectively your team was able to work together during this project." "Engagement" and "effective" were both subject to the students at the time of the survey, but team member engagement and effective teaming were discussed in the team development workshop help between modules 1 and 2. The effectiveness of the teams and the engagement of team members improved over the semester, particularly after the session about teamwork. In addition, the percentage of student who reported

experiencing conflict in their teams decreased from 26% for module 1 to only 14% for modules 2 and 3.

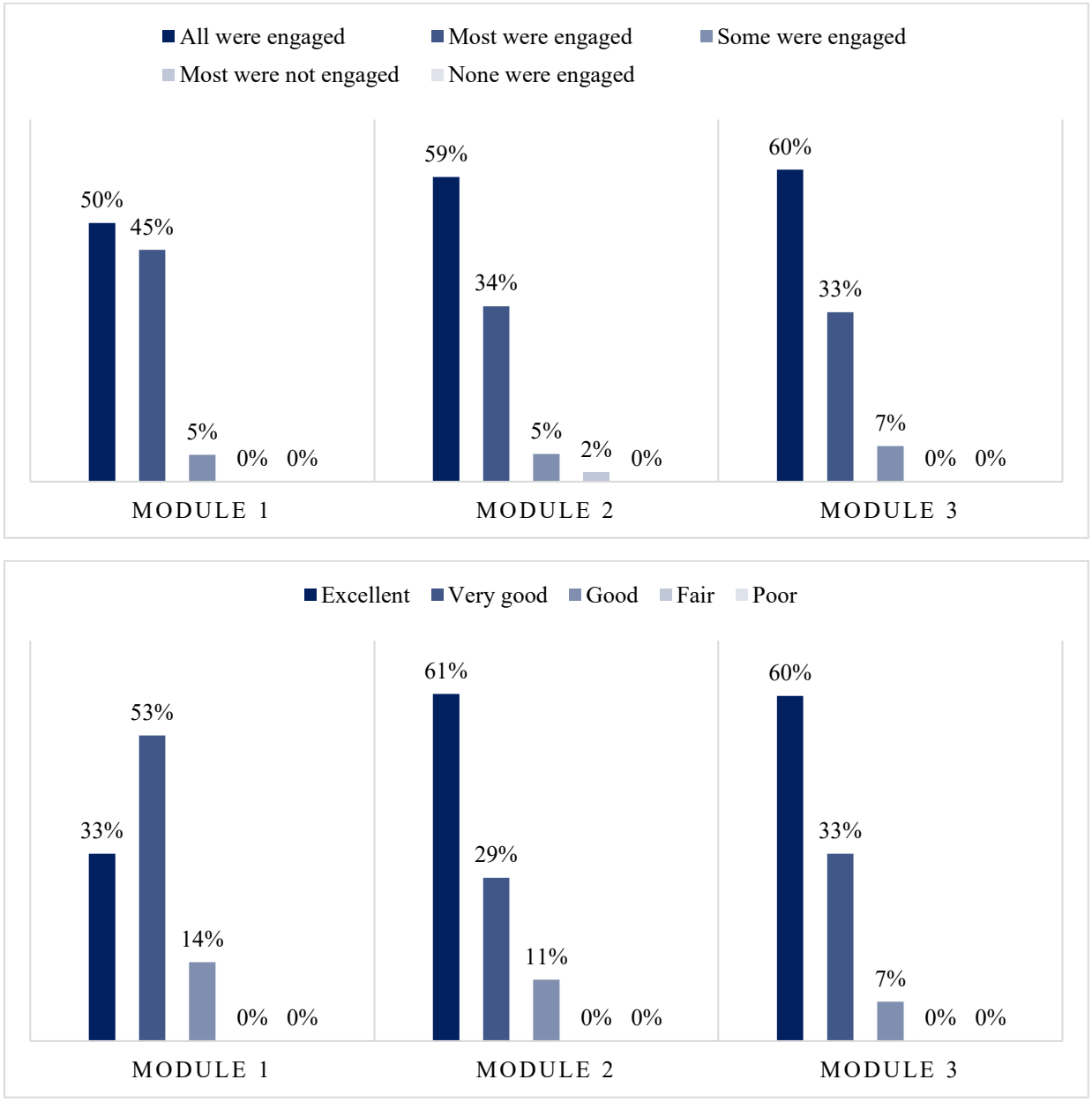

Figure 1: Top: Level of engagement of team members. Bottom: Effectiveness of teamwork during project.

In the CE Systems course, students discussed what motivated them towards civil or environmental engineering, points from a recent lecture on climate change that they felt were impactful, and how those both connect to what they want to do in the future. One student told a story about how their first experience with urban agriculture as a child inspired them to pursue learning about it through grade school, significantly influenced their choice of major, and motivated them to participate in related research as an undergraduate student. Another shared their

passion for addressing environmental injustice and how they were excited to learn more about it in this course. During the values hierarchy activity, a word cloud was generated by the entire class based off the values they thought were important for the sustainability of the system they chose to research, an example of which is shown in Figure 2. Extending these values to norms of society to be further reflected in the design requirements was an opportunity for the students to explore how sustainability considers the impacts and outcomes of the systems on all those who interact with it. For a more practical benefit, by asking students to take note of the values represented in other teams' systems, students were engaged during the project presentations.

Figure 2: Example of a word-cloud created from the values identified by the class during the values hierarchy activity.

Discussion

EM from stories and teams

Using stories and reflection activities can not only solidify students' understanding of themselves as engineers, thereby encouraging the development engineering identity, but these types of activities can also actively engage with the 3Cs of entrepreneurial mindset: curiosity, connections, and creating value. In the case of the introductory reflection video in CE Systems, by reflection on their past inspirations, imagining their future, and connecting with the content of the course, the students' curiosity for what was to come in the course increased. It also helped them to make connections between their major, critical societal issues, and the course objectives - leading to a richer context for the course. Reflection on values and norms also encouraged EM by asking the students to interrogate where the value of a design comes from. By engaging with the values of individual stakeholders and norms of society, they start to identify opportunities to create extraordinary value.

Teamwork is also a critical part of supporting EM. Students cannot successfully express an entrepreneurial mindset without effective collaboration. With first-year students, instruction on how to create a safe team culture was enough to see an increase in team engagement and perceived effectiveness. In Exploring CEE, the teams were small and short-term, but in CE Systems, the teams last the entire semester. The extended time in teams and the increased experience of the students involved required that the teaming instruction be elevated in maturity and nuance. Instead of one workshop as in Exploring CEE, the students received a series of more focused workshops. This resulted in students who applied approaches to enhance psychological safety, purposefully

structure their teams, attempt conflict resolution, and practice conflict management, and see the value of effective teamwork. Anecdotally, while it has not been uncommon for one or two teams to dissolve because of internal conflict at the end of every semester in CE Systems, no such issues have occurred since the introduction of formal team instruction. The team project video also served as an effective method of motivating and exciting the students. Students are asked to pitch three megaprojects out of which the instructor assigned one as their project topic. This was done to ensure that there was no overlap in topics between groups. It also made the teams more excited and curious for the project when they were given their first choice.

EM from failure

Failure has long been incorporated into civil engineering education, often through case studies and more often regarding the technical aspects of specific failures. However, there are important process failures of those case studies as well. According to Lynch and Corbett (2021) entrepreneurial mindset is comprised of two predominant orientations: finding a solution and implementing one. Since the former can be influenced by persistence and willingness to overcome failure [31] and the latter requires collaboration skills and a challenge-engaging mindset [52], directly introducing failure to students emerged as an effective framework to help build their entrepreneurial mindset. "Persist through and learn from failure" is also one of the outcomes associated with entrepreneurial mindset as defined by KEEN, specifically, creating value [23]. In Exploring CEE, when asked to define success at this institution, responses included comments regarding GPA, involvement, improvement, making their family or communities proud, and work/life balance. When the instructors shared the responses anonymously, students related to one another's responses. Later in the same session, students shared sometimes heartfelt stories of previous failures, and were empowered by the instructors and their peers to see that in almost all cases, there is a next part to the story, noting that failure is not the end. While not explicitly a team activity, this session demonstrated the value of creating and acknowledging shared experiences among students. SDL has been shown to encourage students' empathy and connection with others [49] and through this activity, the instructors directed the students to apply that empathy and connection in the context of teams. By helping the students recognize instances of team failures in the past, and prepare for future instances, SDL supported the development of more effective teams. A more focused workshop on overcoming failure in teams was conducted in the CE Systems course. Students reflected on difficulties they overcame during the semester-long project and gave advice to their first-day selves. In a rigorous, fast-paced program, it was valuable to offer the students that chance to take the time to intentionally reflect on what they had learned and experienced over the semester. The students not only recognized their own contributions to their group's success but also readily celebrated the efforts and talents of their teammates. Many of their comments centered around helping, either receiving help from a teammate or helping one, and the positive impact it had had on their experience.

Limitations and Future work

The scope of this paper is naturally limited due to the focus on only one cohort for each course (the fall 2022 semester). As these changes continue in further instances of the courses, we look forward to comparing multiple cohorts before and after said changes. We will also be able to

confirm if the increased retention rate is maintained. Future work includes further integration of focused team-development and story-driven learning in other courses in the curriculum and assessment of the impact of compounding engagement in EML.

Conclusion

Teams are not only an integral part of modern engineering, but they also support students' entrepreneurial mindset by providing a space to engage with the 3Cs collaboratively. Similarly, story-driven learning supports entrepreneurial mindset by engaging with the potential value a student can create given their understanding of their own unique experience. In two civil and environmental engineering courses, team development and story-driven learning were combined to magnify their effectiveness. Presented in the context of navigating failure, this approach resulted in more successful teams who were able to connect with their teammates to create value in their courses.

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