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Analyzing student artifacts to understand how first- and second-year engineering design courses develop entrepreneurial mindsets

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Abstract

This complete research paper explores how students in their first and second years of engineering programs and enrolled in a multidisciplinary design-oriented course sequence develop professionally relevant and entrepreneurial mindset (EM)-oriented skills through their coursework. This work is important since students in their first year of engineering programs are commonly concurrently navigating new expectations of what skills and experiences they will need as an engineer and what skills they will need to succeed in college. To support students in both areas, many institutions offer early-degree-program curricula, like the one studied here, to support engineering skill development, career exploration, and academic preparation. Some previous work suggests that skills and behaviors associated with an EM can be particularly helpful for students as they develop in their first years of engineering. The course sequence studied aims to embed entrepreneurially minded learning (EML) throughout the curriculum, but a recent assessment of how EML is showing up for students in the coursework has not been performed. To explore how students are making connections between their professional preparation and EML outcomes, this work incentivized students to reflect weekly on their coursework to identify how it could support their career interests and goals using prompts aimed at gathering outcome data related to an entrepreneurial mindset. We also collected student resume drafts to see if and how they were representing the EM outcomes of their programs.

Students who reflected were asked to respond to one key question, "What is something you learned or did this week in your course that will help you in your career?" and provided three probing questions to help them reflect on what they learned that week. Those questions were: "What sort of value can what you learned bring to a future career? How might what you learned support your ability to make connections to other disciplines you will work with as an engineer? Did what you learn inspire you to look further into the subject? In what ways?".

We analyzed 263 open-ended responses to the weekly reflections from students in first-year or second-year courses. Using a deductive approach to coding that was guided by concepts relevant to the conceptualization of an entrepreneurial mindset in the Kern Entrepreneurial Engineering Network, we looked for patterns in the kinds of EM outcomes being developed in our courses and the kinds of course-based activities students were demonstrating on their resumes. Beyond providing a robust assessment of how EM develops in early-career design courses, the findings presented demonstrate additional considerations for how to support students in describing their EML outcomes in their professional artifacts.

Introduction

First-year programs are a common feature in engineering education, whereby many aim to concurrently support retention, academic success skill development (e.g., time management, goal-setting), professional skill development (e.g., communication, teamwork), and/or engineering technical skill development (e.g., design, problem-solving) [1], [2]. Among many strategies educators have used to enhance the first-year experiences, some studies suggest the utility of entrepreneurially minded learning (EML) for supporting student development in first-year engineering programming [3], [4], [5]. EML is a pedagogical approach to supporting student learning that supports students' ability to explore, gain insight through connections, and identify value [6]. Similarly, scholars suggest that intentional reflective interventions can support broad student development in first-year engineering programs [7], [8].

While many studies look at the positive impacts of EML and reflection separately, fewer look at how combining EML and reflection can impact student development. In this complete research paper, we explored students' learning through an intervention that combines EML course components with a reflective intervention that leverages concepts related to an entrepreneurial mindset (EM) in the reflection prompts. Given a renewed focus on professional skills development across our curriculum, we sought to explore the intervention's impact on students' professionally relevant, EM outcomes development by asking the following research question:

What professionally relevant skills related to an entrepreneurial mindset are students developing and resonating with in our EML courses?

Background and Motivation

First-year engineering programs, a key emergent feature of engineering programs over the last 100 years, continue to evolve in their goals and scope [9]. Broadly, though, reviews of program trends reveal a balanced emphasis on technical skill development through design and problem-solving opportunities, with professional and academic skill development [1], [2] that remains stable over time. While overarching learning goals for first-year programs are similar across programs, the pedagogical approaches by which programs seek to support learning vary. Two key pedagogical approaches that have been leveraged to support students in developing first-year engineering skillsets include entrepreneurially minded learning and reflections. We detail how those pedagogical choices have been studied in first-year engineering contexts in the following sections.

Entrepreneurially Minded Learning to Support First-Year Engineering

One approach gaining traction in first-year engineering programs is entrepreneurially minded learning (EML) as defined by the Kern Entrepreneurial Engineering Network (KEEN). Stemming from KEEN's definition of Entrepreneurial Mindset (EM), which emphasizes the ability or inclination to demonstrate curiosity about the world, explore contrary views, integrate information to gain insight, assess and manage risk, identify opportunities to create value, and persist and learn from failure, EML describes pedagogical approaches that facilitate these outcomes [6]. Many examples of what it looks like to incorporate EML in first-year engineering exist. For example, a team at The Citadel went through a backward design process to incorporate EML into a first-year seminar course that resulted in a seven-week design project where students design a community park within a set budget and engage with EML outcomes at different phases of the project [10]. Similarly, institutions have performed mapping activities to explore how EML is already supported in their programs to inform further development of activities to support EM development [11]. Some groups have also shared how active learning and EML can be complementarily used to support student learning in first-year engineering programs [12].

Many studies that have implemented EML in first-year programs and assessed the impact on learning outcomes suggest benefits to students that go beyond EM learning outcomes. Many of these studies focus on the supplementary nature of EML for students' technical outcomes development. For example, a study by Grzybowski [4] looking at the differential outcomes between students completing an EML-based design project versus a traditional project indicated gains in curiosity, connections, and creating value indicators (EM outcomes) for the EML teams, as well as strong technical outcomes gains as demonstrated by the course's exams. Preliminary findings in an electrical engineering course also indicated enhanced technical learning outcomes for students by using EML, as evidenced by post-course surveys [5].

Other studies suggest the supplementary nature of EML for students' design outcomes. In one study, researchers found that an EML design experience using Universal Design principles to have students design toys demonstrated EM outcomes as well as strong performance in design outcomes like final prototyping, assembly descriptions, and connections to design criteria [3].

While there are studies that show the promise of EML to enhance students' design and technical learning outcomes, there are other larger-scale studies that indicate small or no differences in student outcomes related to self-efficacy [13], EM outcome development over longer periods of time (i.e., small differences observed in students studied for longer than one year), and motivation or identity [14]. These conflicting perspectives point to a need to further understand how EML in courses contributes to student outcome development. It seems that the field has not yet converged on how courses that leverage EML inspire students to learn more, make connections, and create value.

Furthermore, connections between EML and professionally relevant skills or dispositions that move beyond connections, curiosity, and creating value outcomes of an EM are sparse in the literature. Recent efforts to expand the conceptual thinking of EM have described Habits of an EM, which add skills and dispositions related to Action Orientation and EM Enhancing Foundations [15]. Action Orientation is described as the habits that drive initiative, persistence, and proactive problem solving, and is comprised of five sub-outcomes: initiative, resilience, continuous improvement, adaptability, and resourcefulness. Similarly, EM Enhancing Foundations are habits that enrich EM through ethical thinking, continuous improvement, and self-awareness. EM Enhancing Foundations are made up of five sub-outcomes as well and include: Character, Growth Mindset, Intellectual Humility, Accountability, and Metacognition. Looking at recent literature that describes professionally relevant skills desired in engineering graduates by industry employers, we found strong overlaps in how industry was describing desired professional skills (e.g., ability to communicate effectively with diverse groups, critical thinking, time-management, and self-motivation) [16] and the skills captured in the EM Habits of Mind. For this reason, we leverage the EM Habits of Mind to inform our data analysis.

Reflection to Support First-Year Engineering

Reflection is another commonly leveraged pedagogical tool to support both student learning and instructor assessment in first-year engineering courses. Recent work explored how to best support first-year students to meaningfully engage in reflective activities, providing suggestions for learning outcomes, activities, and evaluation to enhance reflection [7], [17]. Common formats of reflection to support professional development in first-year engineering programs include engineering notebooks [18] and ePortfolios [19], [20], but many of these studies also describe students' desire to have more support when reflecting on and connecting their experiences in the first year to professionally relevant skills. Diverging from more standard ePortfolios and notebooks, a recent intervention using short, weekly reflections demonstrated gendered differences in course-based learning outcomes [8]. As such, we sought to explore how students were connecting EM and career outcomes in optional weekly reflections, which allowed us to explore a reflective intervention that is likely to support student learning.

Early-career engineering students are developing a broad range of skills through their early, multidisciplinary engineering courses. In many cases, students need support to articulate their development through these courses. By developing a reflective tool that asks students to make connections between their desired future careers and their course content each week, we have the ability to explore the outcomes students are connecting to specific course activities and support students' deeper thinking related to their professional development.

Methods

This study employed a qualitative, deductive analysis approach to examine student artifacts (weekly reflections and resumes) for evidence of EM development. Deductive analysis was chosen for its ability to systematically categorize textual data into meaningful patterns aligned with the Habits of EM framework. First and second-year engineering students were tasked with generating these artifacts as part of their course objectives, including optional weekly reflections and initial resume creation. Instructors were contacted by the researcher to collect these artifacts. The researcher for the study requested consent from the students with approval from the Institutional Review Board to collect the artifacts for research purposes.

Study Context

We recruited students from first- and second-year engineering programs who were taking a sequence of interdisciplinary engineering fundamentals courses at a large R2 institution in the Eastern United States. Participants were enrolled in a variety of engineering programs such as biomedical, chemical, mechanical, electrical and computer, civil engineering, and engineering entrepreneurship. In each semester, students completed one or more projects that leverage EML in some capacity. Titles for the projects students engaged in are included in Table 1.

Table 1. Course projects in the courses studied.

First-Year Courses		**Second-Year Courses**	
Fall 2024	Spring 2025	Fall 2024	Spring 2025
1. Toy Block Topper Design 2. Product Sustainability Assessment	One or More of the Following: ● Algae Growth Experiments ● Universal Toy Design ● Reverse Engineering Product Development	1. Bottle Rocket Design	One or More of the Following: ● Tissue Engineering Experimental Design ● Drone Design for Social Good ● Water Quality Experiments and Bridge Design ● Entrepreneurial Design

As multidisciplinary and introductory courses, these courses covered a broad range of learning outcomes. The learning outcomes for each course can be found in the Appendix.

Data Collection

To begin data collection, the lead researcher (author two) provided context for the study to students in several sections of the studied courses. Students who consented to participate could 1) give their instructor permission to share their resumes with the research team, 2) opt-in to a weekly reflective activity and be entered into a drawing for $50 giftcards if they completed 75% of the reflections, or 3) do both 1) and 2). If they opted into the resume portion of the study, the researcher worked with instructors to collect student resumes after grades had been submitted. Resumes were submitted as part of the course deliverables, and students consented to share their artifacts for research purposes. Based on the courses' EML foundations and structure, students were expected to have gained practical experience, providing them with enough content to construct early career resumes. Although a required assignment for the course, there were fewer structural requirements for the resume creation, and much of the information included was at the discretion of the students. This provided valuable insights into what professional skills students developed as they actively decided what items were significant for inclusion on their resumes.

If students opted into the reflections portion of the study, they received a weekly reminder email requesting their reflection for the week to be submitted via a Qualtrics survey. The structured nature of the reflections allowed us to gain additional insights into how students articulate the career relevance of their projects. Students were asked to respond to the following questions:

1. What is something you learned or did this week in your course that will help you in your career?
2. What sort of value can what you learned bring to a future career?
3. How might what you learned support your ability to make connections to other disciplines you will work with as an engineer?
4. Did what you learn inspire you to look further into the subject? In what ways?

Reflection data was collected from a total of 263 students, where 77 reflections were from the Fall 2024 semester, and 186 were from the Spring 2025 semester. Additionally, resumes were examined from 46 students from Fall 2024 and 16 students from Spring 2025. As this is a developmental study to see how well students are demonstrating EML in their career artifacts, no data were excluded from the study. After data collection, resumes were anonymized by removing participants' names/identifying information prior to analysis. This was done to ensure student privacy.

Data Analysis

Coding in NVivo 12 was used for analysis. It followed a deductive coding approach informed by the Habits of EM framework [21]. Deductive coding was used to help us focus our attention on the concepts of interest in the framework, which guided the work [22]. During the coding process, emergent themes and patterns were noted via memoing within the coding software to aid in answering the research question posed. Two rounds of deductive, descriptive coding [21] were conducted on the reflections: the first identified broad EM habits (i.e., curiosity, connections, creating value, action orientation/agency, and EM-enhancing foundations) and was completed by author two, and the second refined subcategories within each habit and was completed by author one. This two-cycle process was completed intentionally to support the reliability and robustness of the coding process [21]. To facilitate coding consistency, the authors discussed and collaboratively resolved any instances where author one did not see alignment with the broad EM habits codes assigned by author two. This peer debriefing ensured reliability, and disagreements were resolved through consensus [21]. Table 2 includes how the EM Habits subcategories were defined at the time of this study.

Table 2. Habits of EM and the subcategories of each habit outcome [15].

Curiosity	**Connections**	**Creating Value**	**Action Orientation / Agency**	**EM-Enhancing Foundations**
Inquisitive *Leans into work with curiosity about our changing world.*	Creativity *Integrates information from disparate sources to spark new ideas.*	Value Awareness *Focuses on solutions where extraordinary value can be created.*	Initiative *Drives progress by initiating solutions and creating forward momentum.*	Character *Considers the ethical implications of decisions.*
Contrarian Thinking *Explores alternative or disruptive views of current or accepted solutions.*	Systems Thinking *Recognizes interdependencies in systems and identifies leverage points.*	Customer-Centric Thinking *Frames efforts in terms of the customer's actual needs.*	Resilience *Bounces back from setbacks and recovers from failures.*	Growth Mindset *Embraces learning and feedback for development.*
Opportunity Seeking *Actively identifies trends and unmet needs to uncover new opportunities.*	Implications Thinking *Anticipates the long-term impacts and consequences of actions.*	Scale *Leverages systems and networks to expand reach and maximize outcomes.*	Continuous Improvement *Continuously refines methods to enhance outcomes.*	Intellectual Humility *Acknowledges limitations, seeks diverse perspectives, and avoids overattachment to one's own ideas.*
Experimentation *Constantly experiments and iterates to refine methods and solutions.*	Strategic Thinking *Develops long-term strategies with clear milestones.*	Persistence *Maintains sustained effort to achieve goals despite obstacles or delays.*	Adaptable *Adapts strategies and pivots to respond effectively to changing conditions.*	Accountability *Takes responsibility for actions, decisions, and their consequences.*
Embracing Ambiguity *Develops comfort with uncertainty to make decisions when information is limited.*	Assess and Manage Risk *Proactively incorporates risk management into decision-making.*	Socially Mindful *Prioritizes creating meaningful and positive societal impacts.*	Resourcefulness *Solves problems creatively with available resources.*	Metacognition *Reflects on thought processes to improve self-awareness.*

The resumes were coded by looking for the presence of the EML projects associated with each course, which helped us further understand what students felt was professionally relevant in the course. As early-career students, it is common to give students guidance to include course-based project experiences on a resume, particularly for students who have not yet participated in relevant engineering clubs or out-of-class experiences. Since we were interested in understanding what students found professionally relevant about the projects we offer in the course sequence, we were particularly interested in observing trends relating to which projects students included on their resumes, or if students included project data on their resumes at all.

Results and Discussion

The analysis of student artifacts provides insights into how first- and second-year engineering design courses foster EM outcomes. Several patterns emerged that highlight both the strengths and weaknesses in current course structures. Overall, we found relatively little evidence of the course-based projects represented on students' early career resumes, and a wide range of depth of descriptions of the projects when they did appear on resumes. However, we saw substantial evidence of EM Habits outcomes appearing in students' weekly reflections on the course content and associated EML projects. Those findings are further articulated below.

EML Projects Represented on Resumes

Across the 46 first-year students, we identified 38 total mentions of EML projects, and 10 mentions from the 16 second-year students who participated in this portion of the study. These counts reflect repeated mentions by some students, as several listed more than one project, whereas others did not list any. When reduced to unique individuals, only 24 of the 54 students included at least one of the course projects shown in Table 1 on their resumes.

There was also a substantial disparity in how students described their project experiences. Some students only provided names of projects, others included minimal descriptive details, and only a few articulated specific skills or outcomes they gained. As an example, one student noted that the projects "provide[s] me with specified skills like research and prototype development". According to the Habits of EM that drove the research conducted, rapid prototyping is considered a valuable EM-related professional skill, and the student demonstrates that the project provided them with the opportunity to execute this skill. Another student's resume discussed the universal toy design project and exemplified the habit of customer-centric thinking through their ability to "[research] market trends in fidget toys to identify popular designs and features". However, other resumes were far less explicit about specific skills acquired within the projects and instead listed the project on their resume, offering no insights into the kinds of skills they developed through the project. For example, one student created a bulleted list that provides the following projects from Table 1: Toy Block Topper Design, Universal Toy Design, and Bottle Rocket Design. However, there was no additional information about the projects, such as their personal contributions to the projects or the skills they needed to meet or exceed performance expectations.

Overall, we saw far fewer instances of the projects represented on students' resumes than expected. Students who captured skills they developed in the projects demonstrated the professional preparation significance of projects, but their descriptions often did not provide strong evidence that they were developing skills related to habits of an EM. While the lack of representation of our projects on students' resumes may point to the potential that students do not see the professional relevance of their projects in the courses studied, we think there may be some element of training needed to help students develop high-quality resumes that may also be impacting our results. Prior research has demonstrated the importance of supporting students' efforts to develop compelling resumes [23], [24], [25], and given the promising evidence of EM outcomes from student reflections on the same course content, we conclude that targeted training on what employers are looking for in resumes may help students better capture their course experiences on their resumes.

Weekly Reflections

The reflection analysis revealed which EM habits students were engaging with most. Their written responses provided concrete examples of the habits they were developing and how those habits emerged in different course experiences. Across both semesters (Fall and Spring) and both academic years (First- and Second-Year), students demonstrated habits from all five categories of EM. Connections appeared most often, likely due to the prompt asking students to relate course content to other disciplines. Curiosity and Creating Value were also common, especially when students engaged with hands-on design activities. Action Orientation was present but largely limited to the sub-outcome, Initiative, which aligned with the prompt asking students about their interest in exploring topics further. Finally, EM-Enhancing Foundations appeared consistently in both semesters, often in relation to teamwork, feedback, and discussions of ethics. These findings are further described in the following sections.

Action Orientation / Agency

Starting with Action Orientation, several students provided answers showing Continuous Improvement, Resilience, and Initiative. To look for patterns in the data, we looked at how frequently Action Orientation outcome subcategories showed up in students' reflections. Within the common outcome subcategories, we saw that examples of Continuous Improvement were typically present when students reflected on their iterative design processes and acknowledged that redesigning was an important part of being a professional engineer. For example, one student reflected on the concept of convergent and divergent thinking, stating that they "brainstormed unique ideas while refining and converging on practical solutions for a 3D printed model" and that this is an "essential tool for engineering". Similarly, resilience appeared when students would push forward despite struggling with something related to a project they were working on. An anecdote from another student discussed the design process of their product and the struggles they had encountered. They reflected on the experience saying, "Through hard work and persistence along with engineers with different majors we solved problems on our feet during a timed duration". These findings suggest the complementary nature of EML for supporting technical (i.e., design) and academic success (i.e., resilience) outcomes that are commonly emphasized in first-year engineering programs [1], [2].

Contrary to the Continuous Improvement subcategory of Action Orientation, instances of the subcategory Initiative were typically unrelated to the EML projects in students' courses. Instead, students stated that a concept or topic introduced in the course inspired further research on a subject outside of the class as opposed to advancing a project's efforts. For example, a student said, “Finally, what I learned this week inspired me to pursue the next steps of my goals and look for internships”. Furthermore, habits such as Adaptability and Resourcefulness from Action Orientation were notably absent, likely because prompts did not encourage students to reflect on managing uncertainty or leveraging limited resources. These patterns align with research on reflection, suggesting that the reflective activity itself can have an impact on learning [17], and encouraging us to revisit reflective prompts for future iterations of this intervention.

Connections

Instances of connections occurred most frequently among all of the habits of EM outcomes. Strategic Thinking, Creativity, and Systems Thinking occurred most often. Furthermore, there was a noticeable growth in both Systems Thinking and Strategic Thinking from the Fall to Spring semester, suggesting that, count to other intervention studies on short term gains in EM outcomes [14], the reflections may be helpful for noticing gains in EM outcomes over shorter time periods.

One student demonstrated Strategic Thinking through a design experience that they then translated to other educational areas, remarking that “I have looked further into the idea of redesigning, [and] I have redesigned the way that I do my math homework”. Similar to what we saw in the Action Orientation outcome, where EML was supporting not only professional skills but academic success skills as well, we saw that this student took a concept relevant to their project and applied it elsewhere as a strategy that will be beneficial to them long-term. Additionally, there were often excerpts from the students’ writing that reflected a combination of two Connections-related habits. For example, one student described how new software assisted them in the course and their future, remarking, “Tasks such as large calculations or common plot formation [are] typically used in production stages and presentation stages of projects, making this a valuable source for computation or visualized data”. This reflection demonstrated Strategic Thinking, as the student recognizes the software’s usefulness beyond the immediate assignment, and Systems Thinking, as they identified how these tasks occur across different stages of a broader engineering workflow. There were not many instances of Assessing and Managing Risk, though some students mentioned better understanding cost effectiveness and efficiency, or how companies sometimes “sacrificed durability to save some cash” as it related to design-specific content they experienced. Assessing and Managing Risk also only appeared in Spring 2025 data, potentially demonstrating evidence that Spring semester EML projects in the First-Year and Second-Year courses were better supporting the development of this outcome, pointing to a benefit of nuanced assessment of EML activities for supporting specific EM outcomes. Similarly, Implications Thinking was far more prevalent in Spring 2025 and was most often demonstrated through students’ newfound understanding of engineering ethics and ethical decision-making, topics that are more prevalent in the Spring semester projects.

Creating Value

Within the Creating Value outcomes, reflections most often demonstrated Customer-Centric Thinking and Scale subcategories. Fall 2024 reflections had many instances of Persistence, likely as a result of the First-Year course’s strong emphasis on academic success topics. Similarly, Spring 2025 had many instances of Value Awareness and Socially Mindful subcategories, which we think was a result of the Spring semester project topics (e.g., universal design, drones for social good). These differences suggest the benefit of EML for academic and professional outcomes like those studied to not be strongly impacted in prior work [13], [14].

In both semesters, Customer-Centric Thinking appeared when students needed to deliver a product to another audience and adjust their approach to suit the audience's needs. A common example of this occurred in an EML project where students designed a toy for children. Many students discussed receiving feedback from children testing their prototypes and taking the information as "potential improvements for our design". Similarly, Scale was present as an outcome in projects where students considered reaching larger audiences and making their project accessible to a wider audience. In the project where students designed a toy for children, students reflected on Scale in terms of how they could make the toy more accessible for children of all ages, sizes, cognitive development, etc. In our data, Persistence tended to show up in reflections by first-year students who were struggling to grasp a concept or idea and persisted in moving forward in their learning. The fall first-year course places a strong emphasis on academic success strategies in addition to hands-on projects, which may explain why persistence showed up more frequently in the Fall reflections. Furthermore, Spring 2025 artifacts showcased the development of new habits associated with Creating Value. Many students discussed the idea of Engineering Ethics in Spring 2025 and how that knowledge allowed them to be more aware of the social impacts their decisions can have if they do not abide by a code of ethics. Similar to other semester-based patterns already presented, ethics was a topic more frequently covered in Spring semester projects, so these results further support the idea that EML can be designed to support specific facets of EM outcome development.

Additionally, students started seeing value in the concepts taught in the classroom and spent time reflecting on other ways they can bring value. The most common example of Value Awareness in this context was when students reflected on a project related to algae and the many potential uses of it that they were previously unaware of. This sparked new ideas for students, like one student who wrote, "I am now thinking about the multiple possibilities that algae have in the biomedical engineering, tissue engineering, and medical treatment world". The consistent reflection on value in student reflections across both project-based and other topic-based EML class activities suggested to us the value of 1) EML in the courses we studied, and 2) directed reflective activities for outcome development [17].

Curiosity

Within Curiosity, Inquisitive, Opportunity Seeking, and Experimentation were all common subcategories. Inquisitive natures presented themselves when students became more interested in a subject and researched it further after a classroom discussion or activity. An example of this was shown when a student discussed how working through different statistical analysis methods left the student "more interested in exploring how data-driven approaches can address environmental challenges, potentially influencing my future work in sustainable engineering". One notable finding was the influence of reflection prompts on the habits students demonstrated. For example, Inquisitive appeared frequently, largely because the final reflection questions explicitly asked whether students were inspired to explore topics further. This finding supports that reflection design plays a critical role in shaping which EM habits students articulate [17]. It also brings into question whether the students are learning missing habits or just not reflecting on them unless directly stated, which has encouraged us to revisit the reflective prompts for the next iteration.

Opportunity Seeking was often seen in tandem with Inquisitiveness in researching a topic. However, there were some instances where students were inspired by their class and sought out new opportunities, such as one student who stated, “After setting up this experiment, I finally wrote to a professor in the BME (biomedical engineering) department to possibly join a research lab”. Spring 2025 showcased two unique subcategories: Contrarian Thinking and Embracing Ambiguity. Contrarian Thinking often occurred when students needed to view a problem from multiple unfamiliar viewpoints, such as considering stakeholders beyond just the consumer in a project. A common example of this was related to the universal toy project, where students realized that although children are the consumers, parents are the ones purchasing Happy Meals, would need to find a toy suitable for their children, and that they need companies to mass-produce the toys, which can affect the trajectory of their design. One student captured this perspective when they wrote:

> Our consumers for this project are the children who are using the toy and receiving a happy meal. On the other side, the parents/guardians are going to be buying the happy meal and toys. However, to mass produce these toys that we are designing a major company might want to buy our design and product.

Last, students learned to Embrace Ambiguity when information was limited. Instead of being defeated, students demonstrating this outcome reflected on moving forward in making decisions or, more commonly, continuing to learn a difficult-to-grasp topic. Previously, Persistence was shown in Fall 2024 and not at all in Spring 2025. Similarly, Embracing Ambiguity is not demonstrated in Fall 2024 but exemplified several times in Spring 2025. Although this might suggest growing confidence over time, as studied as a desired outcome of EML in literature [14], the explanation is likely more nuanced. Because the fall and spring data include both first- and second-year students, and because the projects varied between semesters, these patterns may reflect the nature of the assignments as much as the developmental stages of the students. It seemed instead that a key takeaway of our work was that certain projects or prompts may naturally elicit different habits, highlighting the importance of EML assessment at the project level.

EM-Enhancing Foundations

Each of the five subcategories in EM-Enhancing Foundations (i.e., Character, Growth Mindset, Intellectual Humility, Accountability, and Metacognition) occurred in both semesters. Examples of Character tended to occur in reflections when there were lectures on engineering ethics. Though not directly related to a project, these EML activities provided spaces for students to be more open-minded and consider the ethical implications of decisions they will face in their futures. Ethical decision-making and subsequently, character as described in the habits of EM, are important outcomes in many engineering programs, as demonstrated by their inclusion in ABET outcomes [26]. While students did not tie Character as an outcome to an element of the projects in our course, it was promising to see other elements of the course helping students develop this outcome.

Students also often demonstrated Intellectual Humility when realizing their limits on their own, and the power in approaching projects from different angles with the help of others. One student commented that "having other perspectives aided the capabilities of our project and made it more refined", which was a common sentiment amongst students, regardless of the project. Additionally, Growth Mindset occurred in different ways. In some cases, students realized that constant iteration only benefited their project, not hindered them. One student illustrated this by writing "you need to deliver good work, and if your work isn't good, redesign till it is". In other cases, students reflected on how criticism is typically difficult for them to take, but began to realize the importance of critique in improving themselves. One student reflected, "Taking constructive criticism is something I have struggled with during my career. It feels personal when someone tells you your effort didn't result in the best product" but immediately follows up with "However, moving forward this criticism will provide me with an outlet of reflection". An interesting result was that Metacognition and Accountability tended to occur concurrently. For example, students described holding themselves or their team accountable when poor time management caused project setbacks. They also indicated that these experiences prompted reflection on the importance of planning and prioritization moving forward.

Conclusion and Future Work

This study examined how students in a first- and second-year engineering design sequence that leverages EML demonstrated professionally relevant entrepreneurial mindset (EM) habits through weekly reflections and early-career resumes. Across 263 reflections, students showed evidence of all five EM habit categories, with Connections, Curiosity, and Creating Value appearing most frequently. These habits were especially visible in hands-on, open-ended EML projects, where students reflected on systems thinking, customer-centric thinking, opportunity seeking, and ethical considerations. In contrast, Action Orientation habits such as adaptability and resourcefulness rarely appeared, suggesting that either the prompts or the project structures did not consistently elicit these behaviors. Further, students connected some EM Habits subcategories more consistently to non-project EML activities, suggesting a need for further detailed exploration of the subcategory outcomes being developed from any given EML activity.

And while reflection data indicated strong EM outcome development, resume data painted a different picture. Few students included course projects at all, and those who did varied widely in how clearly they articulated the skills that they developed. This disconnect suggests that students may be practicing EM-related behaviors but are not properly equipped to translate those experiences into those considered valuable in professional artifacts. Strengthening resume instruction and helping students make connections between project work and professional skills may improve how they represent themselves to future employers.

While this work provides a more nuanced understanding of the EM habits that students are developing through the EML projects in our course sequence, it is not without limitations. This study is limited to one institution and two semesters, which may constrain generalizability. Resumes, in theory, should have demonstrated EM outcomes, but due to guidance not being provided to students to the same extent as the explicitly stated questions in a reflection, it was difficult to determine patterns and conclusions, indicating that future research in this area is needed. Although required for the course, students volunteered their artifacts to be included in the study, resulting in sample size limitations and selection bias. The study also primarily implemented deductive coding, which limits the scope of the outcomes that were observed. Based on the patterns we observed in our data, we recommend that future research continue to explore longitudinal development of EM habits, examine how reflection quality influences habit development, and investigate strategies for integrating more opportunities to develop subcategory outcomes, such as Adaptability and Resourcefulness, into early engineering curricula. Furthermore, a more mixed-methods approach, including quantitative data collection that measures EM habits outcomes through validated surveys alongside reflections, could provide a more comprehensive understanding of EM outcome development.

Overall, our findings demonstrate that EML activities and structured reflection can meaningfully support early-career students' development of EM habits, even if these outcomes are not fully reflected in their career artifacts. At the same time, differences across semesters and project types indicate that course design and reflection structure strongly influence which habits emerge. Understanding these habits is essential for developing future interventions that promote habit development and better prepare students to communicate their professional skills.

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Appendix

FEC I Course Objectives

1. Collect, record, analyze and interpret technical data to evaluate an object or system of engineering interest;
2. Demonstrate curiosity about and articulate how the context (People/Planet/Prosperity) in which engineering is practiced impacts solutions and designs;
3. Differentiate and make connections between the contributions of different engineers (majors and professions) in the development of a product, process or system;
4. Function effectively on a team with individual and joint accountability;
5. Apply the formal engineering problem solving method and present problems and solutions in standard engineering format;
6. Communicate engineering concepts, ideas and decisions effectively in a variety of formats;
7. Evaluate and implement proven (research-based) academic success strategies.

FEC II Course Objectives

1. Describe principles related to product development and apply them to create value for diverse populations;
2. Perform quantitative analysis on engineering design problems using statistics, economic analysis, and programming;
3. Determine critical product development criteria and explore alternative solutions to open-ended engineering problems;
4. Explain and draw connections between engineering science principles such as mass, momentum and energy balances, materials, and thermodynamics using consumer products or engineering as a test bed;
5. Evaluate scientific principles, material properties, manufacturing techniques, cost, safety requirements, environmental considerations, and intellectual property rights within the context of ethical engineering behavior;
6. Work effectively in problem-solving teams and carry out meaningful performance assessments of individual team members;
7. Develop technical communication skills in written, oral, and graphical formats

SEC I Course Objectives

1. Analyze the audience and account for competing and/or overlapping needs of different stakeholders (Creating Value)
2. Select the best way to address audience and context needs for a given communication task (Connections)
3. Present technical information effectively to different audiences
4. Define area of inquiry through the exploration of knowledge gaps (Curiosity)
5. Use library's engineering databases and internet to select best sources
6. Comprehend and synthesize information from multiple sources (Connections)
7. Use research to effectively inform design decisions (Curiosity)
8. Write effectively in various engineering genres

9. Use conventions of academic writing and citation appropriate for engineering documents
10. Develop skill with technical writing tasks such as description
11. Understand the importance of data presentation, data usability, and ethics
12. Produce effective writing in a short time period
13. Collaborate with team members
14. Generate multiple engineering design solutions using convergent and divergent design (Curiosity)
15. Apply sound engineering principles to choose the best solution based on customer requirements, and see it through to completion (Creating Value)
16. Use parametric design to optimize an artifact or process
17. Demonstrate awareness of the sustainability implications of a solution (Creating Value)

SEC II Course Objectives

1. Appropriately analyze diverse audiences and apply such analyses to communication.
2. Effectively use a variety of supporting material in their communication.
3. Develop and maintain audience interest in their communication.
4. Research, design and deliver an effective informative, technical, and persuasive speech. Adapt technical information to a non-technical audience.
5. Adapt presentation content and delivery based on audience analysis.
6. Recognize the different purposes and structures of informative and persuasive communication.
7. Synthesize and incorporate research for use in oral presentations (Connections).
8. Recognize and utilize effective visual aids for presentations, as well as graphical strategies for communicating information in reports.
9. Recognize the need, identify the customer, assess the market, and define the goals, objectives, and constraints for a design problem (Connections, Creating Value).
10. Generate multiple engineering design solutions using various techniques (Curiosity).
11. Perform appropriate engineering analyses and choose the optimal solution based on these results (Creating Value).
12. Apply communication skills effectively to describe and validate design decisions.