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Incorporating an Entrepreneurial Mindset in Online Introduction to Engineering Courses: A Study of Value Creation

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Short Abstract

This study examines the impact of integrating entrepreneurially minded learning (EML) principles into an online Introduction to Engineering course at Arizona State University. The intervention focused on value creation, encouraging students to consider the political, economic, social, technological, legal, and environmental impacts of their designs. Quantitative data from pre- and post-surveys were analyzed using independent t-tests, while qualitative data from student reflections were examined using thematic analysis. Findings indicate significant improvement in students' entrepreneurial mindset ($p < .01$); however, quantitative measures of value creation did not show statistically significant changes. Qualitative findings suggest students valued collaborative problem-solving and the use of structured decision-making tools, such as decision matrices. Even small interventions can influence online students' entrepreneurial mindsets.

Introduction

There is a growing need to better understand how intentional course design embedding entrepreneurial mindset (EM) principles impacts engineering education [1, 2]. Specifically, such design interventions can influence students' ability to apply EM to real-world engineering problems and deepen their understanding of value creation with attention to societal effects. As the demands on engineers evolve, students must develop not only technical expertise but also a mindset capable of addressing broader societal challenges. EM principles—centered on curiosity, connections, and value creation—offer a robust framework for cultivating these essential skills [3].

This study investigates the impact of an intervention aimed at fostering entrepreneurially minded learning (EML), with a particular focus on value creation in the engineering design process. The research question guiding this work is: *How does embedding EML principles influence students' ability to apply an entrepreneurial mindset and value creation in engineering design?*

Entrepreneurial mindset (EM) is a multifaceted concept that varies across disciplines, including engineering and business, with each field emphasizing distinct yet complementary attributes. Despite variations in definition, EM generally encompasses key competencies such as leadership, opportunity recognition, innovation, and adaptability [3, 4]. In engineering education, EM extends beyond technical expertise to a holistic approach that integrates problem-solving with a mindset of curiosity, connections, and value creation—commonly referred to as the 3Cs framework.

Entrepreneurially minded learning (EML) is a pedagogical approach that integrates EM principles (e.g., 3Cs) into engineering education [5, 6]. EML aims to develop students' ability to recognize opportunities, think innovatively, and generate solutions that have economic, social, and environmental impact.

Value creation, or creating value of the '3Cs framework', is the process of identifying and developing solutions that generate meaningful benefits for individuals, organizations, or society by addressing unmet needs, improving efficiency, or enhancing experiences [3, 5, 6]. The concept of value creation encourages students to assess the broader impacts of their designs, including political, economic, social, and environmental considerations [7, 8]. By fostering this mindset, students are inspired to pursue opportunities that generate sustainable and significant societal benefits.

Many researchers have focused on the in-person classroom context [9, 10, 11, 12], and the online modality could benefit from further study. This research addresses this gap by examining the integration of EM principles in an online, first-year engineering course and evaluating their impact on students' skills and mindsets. This work provides valuable insights for engineering educators and curriculum designers. By demonstrating how small-scale interventions in online courses can foster an entrepreneurial mindset and enhance value creation, this research highlights strategies for improving the student experience. Additionally, it highlights how intentional changes in course design enable students to connect their coursework to complex, real-world engineering challenges. Ultimately, these findings contribute to broader conversations about adapting engineering education to meet the evolving demands of industry and society.

Methods

Online Introduction to Engineering Course Context

This study was conducted in the context of an online Introduction to Engineering course offered at Arizona State University (ASU). The course was an accelerated, 7.5-week summer session designed for students enrolled in online-only degree programs in the Ira A. Fulton Schools of Engineering. The course covered topics such as the engineering design process, teamwork and project management, computer-aided design (CAD), circuits, and Arduino. Assignments included quizzes and technical practice, discussion board posts and responses, as well as a short introductory design project.

EML principles were integrated into each class session through learning objectives, content, readings, and activities. Students were provided videos and resources regarding EM and value creation. In one assignment, students identified issues from their daily lives that could be addressed through engineering solutions and shared them on a discussion board. Their peers researched and proposed potential solutions, which the original student evaluated based on their own value criteria. This activity highlighted the importance of customer-focused, value-driven engineering design.

A major component of the course was a team project where students applied EML concepts to design a swarm of robots using Arduino technology. Students worked in teams of 3-4, with each team member designing an individual robot that performed a smaller task contributing to a shared solution. The robots in the swarm had to communicate and work together to address a self-selected problem. This project aligned with multiple course learning objectives by requiring students to apply customer-focused design and the entrepreneurial mindset to create and evaluate engineering prototypes, work effectively as part of a design team, and communicate their designs through technical reports and multimedia presentations. The project began in week 3 and included five (5) deliverables: problem definition, robot ideation, CAD designs for each individual robot, Arduino circuits/demonstrations, and a final video pitch. Each assessed students' ability to define engineering problems, justify design decisions, and demonstrate technical functionality.

The final project emphasized value creation by encouraging students to frame their problem as a real-world challenge, with their solutions offering societal, environmental, or economic impact. During the problem definition phase, students explored stakeholder needs and how their robot swarm could deliver meaningful value, guiding their design process. To further motivate students, the course also included a case study highlighting how a university student successfully transitioned an idea into a business venture in sustainable farming.

For the final deliverable, teams pitched their solution to a hypothetical panel of stakeholders. This pitch included a value proposition, market potential, and benchmarking, which compared their solution to existing market alternatives and highlighted its added value. By connecting technical skills (e.g., Arduino and CAD) with entrepreneurial problem-solving, students developed impactful solutions.

Student Participants

The study was conducted during the summer of 2024 in one section of the Introduction to Engineering course. The section included 74 enrolled students whose assignments were analyzed. Of these, 52 students responded to the pre-survey instrument described below, and 31 completed the corresponding post-survey. Survey participants were predominantly male (83%), with 15.5% identifying as female; the remaining participants did not specify their gender.

Students represented a diverse range of academic levels: the majority were first-year students (77%), followed by second-year (19%) and third-year students (4%). They also came from a variety of engineering disciplines, including Mechanical Engineering (34.6%), Electrical Engineering (26.9%), Computer/Software Engineering (23.1%), Engineering Management (9.6%), Human Systems Engineering (3.9%), and Biomedical Engineering (1.9%).

Most students identified as white (59.6%), with others identifying as Hispanic (11.5%), African American (9.6%), Asian (7.7%), Multi-ethnic (5.7%), and Native American (1.9%). A small percentage (4%) preferred not to disclose their ethnicity.

The student population in this class is composed of individuals with diverse educational journeys. Most are not recent high school graduates, and more than half bring experience from technical industries and trades such as machining, electrical work, nuclear, construction, and military service.

Overview of the Survey Instrument

The instrument for this study was generated from literature on EM, EML and value creation [6, 9, 12]. The survey presented demographic questions along with measures of EM, value creation in engineering design (VCED), and value creation attitude and approaches (VCAA).

The post-survey additionally included Likert scale items (n=8) and open-ended questions (n=2) for course evaluation. The first four Likert-scale questions on the instrument asked participants to rate their ability to define, identify, apply EM and the 3C's on a 5-point scale where 1 = No Ability and 5 = Outstanding Ability. These items were adapted from the Ita et al. (2023) instrument [9].

VCED was assessed using adapted versions [6, 9, 12] tailored to the behaviors in engineering design context. Students ranked 8 items (e.g., "I explore multiple solution paths to a given problem") on this measure using a scale from 1 to 7 where 1 = Does not describe me at all and 7 = Completely describes me. VCAA was assessed using 12 items adapted from instruments [6, 9]. Students ranked 8 items (e.g., "I seek out opportunities to determine what is valuable to others") The scale ranged from 1 to 7 where 1 = Does not describe me at all and 7 = Completely describes me.

See Appendix A for pre- and post-survey instruments.

Data Collection

Following IRB approval in May 2024, students were recruited through course announcements. Participation was voluntary and not tied to grades.

- **Pre- and Post-surveys**: Surveys were administered at the beginning and end of the course to assess students' entrepreneurial mindset abilities and attitudes toward value creation. Likert-scale items measured self-reported confidence in applying EM principles, while open-ended questions provided additional insights. Student demographic data was also collected. We received 52 responses on the pre-survey and 31 responses on the post-survey. Since surveys did not ask for identifying information, same participants may/may not have participated in the pre and post surveys.
- **Student Reflections**: Open-ended reflection data was collected from student assignments, online discussions, and individual reflections. A specific prompt was chosen for this study: *"How did this course develop your perspectives of value creation? Consider the following as you write your answer: In what ways have you grappled with the notion of value (political, economic, social, technological, legal, and environmental impact) in this course/project? How would you handle a situation where improving technological advancement might increase societal costs? What value did this course create/generate for you?"*

Data Analysis

Both quantitative and qualitative data were analyzed. The quantitative analysis process involved administering a pre-post survey to measure students' self-reported abilities in defining and applying the Entrepreneurial Mindset (EM), as well as their understanding of and attitudes toward value creation in engineering design. Before conducting the primary analysis, normality and reliability checks were performed to ensure the validity of the t-test results. Normality was assessed using the Shapiro-Wilk test and by examining skewness and kurtosis values. The reliability of the three survey constructs (EM, VCED and VCAA) was evaluated using Cronbach's alpha to determine internal consistency (see Table 1).

Next, an independent samples t-test was performed for each construct to evaluate changes in pre- and post-survey responses. An independent samples t-test was used because the surveys were anonymous and we did not have sufficient responses in the post to create paired samples. The t-tests were conducted for each survey construct to determine whether the observed differences in mean scores were statistically significant. The analysis was carried out using SPSS statistical software.

Thematic analysis (TA) was used to analyze the individual student reflection responses. Thematic analysis, as defined by Braun and Clarke, is "a method for systematically identifying, organizing, and offering insight into patterns of meaning (themes) across a data set" [13, p. 57]. This method provided a structured yet flexible framework for identifying recurring themes and gaining insight into students' engagement with EM principles and their understanding of value creation.

The analysis followed Braun and Clarke's six-step process [13] for TA while incorporating coding strategies such as initial and pattern coding outlined by Saldaña [14]. The six TA steps are as follows:

1. Familiarize yourself with the data
2. Generate codes
3. Search for themes
4. Review potential themes
5. Define and name themes
6. Report out

To ensure the trustworthiness of the thematic analysis, several quality assurance measures were implemented. Peer debriefing [15] was conducted with the co-authors of this paper to review a sample of coded data and provide feedback on the coding framework and interpretations conducted by the first author. These discussions were important in refining themes and descriptions. Reflexivity was also integral to the process. Reflexivity [13] emphasizes the active role of the researcher in coding and theme development, highlighting the inevitable subjectivity of these processes and the importance of reflecting on one's values, assumptions, and practices. Researcher memos [16] were maintained by the first author to document assumptions and decision-making throughout the analysis.

Results

Quantitative

The outcomes of the independent samples t-test revealed significant differences in the scores for general EM and 3C related items ($p < 0.01$) before and after the course. However, the results did not yield empirical evidence supporting a statistically significant difference in VCED or VCAA (Table 1).

Table 1. Descriptive Statistics, Reliability Scores and t-test Results for EM and Value Creation Measures

Measure	Pre		Post		Post-Pre	Cronbach's Alpha	t	p
	M	SD	M	SD	M			
EM	2.15	1.01	4.00	0.53	1.85	.903	9.537	<.001*
VCED	4.73	0.79	4.88	0.71	0.15	.817	0.921	.360
VCAA	4.64	0.89	4.85	0.86	0.21	.886	1.046	.299

Note. Means and standard deviations computed from responses (N = 52 for pre and N= 31 for post). EM measured on a 5-point scale and VCED and VCAA measured on a 7-point scale.

Qualitative

Thematic analysis revealed four major themes and thirteen subsumed codes related to students' understanding of value creation. Table 2 summarizes the themes and codes along with anonymous student quotes. Each quote in the table represents a response from a unique student.

Table 2. Themes and Codes from Value Creation Student Reflections

Theme	Description	Subsumed Codes	Example Quotes
Challenges and Constraints	This theme captures the barriers and limitations students encountered while engaging with entrepreneurial mindset (EM) principles and value creation. It includes misconceptions about EM, lack of growth in understanding value creation, and practical challenges such as time constraints that hindered deeper exploration of these concepts.	● Misconception of EM ● No New Insights on Value Creation ● Time Constraints and Prioritization	"Honestly I really don't have the mind to think about and remember perspectives of value, and politics and such." "Being that I am already employed, I felt that it was not much value added for myself." "With the condensed time schedule I feel like not enough time was available to properly vet our value proposition. By the nature of the course much more time was spent on the design vs. EM. Ideally, more time could've been spent in the planning phase of our project to get after a more targeted market and job to be done."
Expansive Thinking	This theme reflects how students broadened their perspectives on value creation through collaboration with others, thinking creatively, and empathizing with stakeholders. It explores their ability to think beyond traditional engineering solutions, incorporate stakeholder needs, and apply innovative approaches to create meaningful value.	● Collaboration for Value ● Creative Thinking in Value Creation ● Empathy and Customer Discovery	"One thing that really stuck with me was when I was watching a lecture and the professor said, 'when creating a toy, you aren't creating the toy itself, you are creating play' I think the idea behind understanding what you are creating and not creating junk really made me think about what I want to design and build. Creating value is creating something with a need. Creating it to fill a void and not creating just to create." "I would handle the situation with different values colliding sensitively, as I think I did this time. Respectfully getting input from others, weighing it and letting the options sink in." "My background as a military service member who was tasked with making the most of what was provided made me think outside the box. I used this skill to look at things through a different lens of how to possibly improve on something that works okay to works for everyone in an

			optimal way..”
Grappling	This theme highlights the processes students employed when faced with complex trade-offs and competing priorities in value creation. It includes reflections on balancing economic, social, environmental, and technological values, using data-driven tools to inform decisions, and considering ethical implications of their choices.	● Data-Driven Decision-Making ● Navigating Trade-offs ● Ethics of Value Creation	“This course deepened my understanding of value creation across economic, social, technological, political, and environmental dimensions. I learned to balance profit with sustainability, corporate social responsibility, and technological advancements while considering societal impacts. It emphasized navigating regulatory frameworks and promoting environmental stewardship.” “If there were two different values that conflicted, I would analyze each value through the AHP chart, take the weighted points from that and use the decision matrix to determine which value is the best for a solution.”
Utility Value	This theme focuses on the practical and personal value students derived from the course, including its impact on their academic preparation, career aspirations, and technical skill development. It also captures their recognition of the real-world relevance of value creation principles and how these concepts can be applied to solve pressing societal and professional challenges.	● Academic Alignment ● Career-Oriented Value Insights ● Practical/Real-world Relevance ● Technical Skills Gained	“This course gave me a better understanding of the design process and design-making techniques to create a project.” “The main way this class generates value for me is as a groundwork for the future education and learning I will experience.” “The holistic approach to resolving conflicting values will be invaluable in my future… career, helping me make informed, sustainable decisions that benefit both organizations and society.” “It helped me develop my own process to go along with the engineering process. It showed me how to determine a path to bring my ideas to life.”

Discussion

Implications

The research question guiding this work was: *How does embedding EML principles influence students' ability to apply an entrepreneurial mindset and value creation in engineering design?*

The quantitative analysis revealed a significant improvement in students' general entrepreneurial mindset (EM) abilities ($p < 0.01$), while changes in value creation-specific measures (VCED and VCAA) were not statistically significant. This contrast suggests that while students develop a broader entrepreneurial mindset through short-term interventions, fostering deeper value creation competencies may require additional time, scaffolding, or course structure modifications.

The qualitative findings provide deeper insight into students' struggles and successes in applying value creation principles in a short-term, online setting. Our thematic analysis offers insight into these results by identifying key barriers that may have influenced students' engagement with value creation principles. Specifically, *Time Constraints and Prioritization* emerged as a major challenge, as students in an accelerated 7.5-week online format had limited opportunities for iterative refinement of their value-driven designs. Additionally, the theme of *Misconception of EM* indicated that some students associated EM primarily with business ventures rather than a mindset applicable to engineering design, potentially impacting their ability to fully integrate value creation principles into their work. These findings align with prior research emphasizing that external pressures—including work obligations, financial stress, or limited synchronous collaboration—can shape student engagement in online engineering courses [17].

Despite these challenges, the qualitative findings illustrate progress in students' conceptual understanding of value creation. The theme of *Expansive Thinking* reflects how students broadened their perspectives by engaging in collaboration, creative thinking, and stakeholder empathy. For example, reflections under *Collaboration for Value* describe how teamwork helped students integrate diverse viewpoints into problem-solving processes, while *Empathy and Stakeholder Engagement* highlight students' growing consideration of customer needs in design decisions.

The theme of *Grappling* captures students' efforts to navigate complex trade-offs and ethical dilemmas. Reflections coded under *Ethics of Value Creation* and *Navigating Trade-offs* demonstrate how students balanced societal impacts, sustainability, and technological advancements. These reflections provide a deeper layer of insight, where students demonstrated awareness of competing priorities, such as economic feasibility versus environmental responsibility—elements not captured in the quantitative findings alone.

The theme of *Utility Value* emphasizes how students connected the course content to their personal and professional development. Reflections under *Career-Oriented Value Insights* and *Practical Relevance of Value Creation* indicate that students recognized the applicability of value creation principles to real-world engineering challenges and their future engineering profession. Additionally, *Technical Skills Gained* code showcased the perceived practical benefits of learning tools like CAD and Arduino programming.

Together, these themes demonstrate that while general EM abilities can be effectively developed through short-term interventions, fostering nuanced value creation attitudes and skills may require more time and targeted engagement.

Building on these findings, future research could investigate the impact of the team-based swarm robotics project on students' entrepreneurial thinking and value creation skills. Given that emerged a theme in shaping students' understanding of value creation, a more in-depth analysis of team interactions, role distribution, and decision-making processes could provide additional insight into how students negotiate value-driven design choices in a project-based setting. Past researchers have also attempted to assess coverage of EM behavioral outcomes, including developing value creation skills, in online, first year engineering courses [12]. Further qualitative research on entrepreneurship and EML is needed to explore these nuances [7].

Recommendations and Broader Applications

While this study focused on a single online engineering class, the challenges of time constraints and value creation scaffolding are likely applicable to other online engineering programs, hybrid courses, and certainly even in-person learning experiences.

Several recommendations emerge from the findings for engineering education faculty, administrators, researchers, and designers:

- **Allocate additional time or resources to explore nuanced aspects of value creation:** Reflections under *Grappling* suggest that students valued structured tools, such as decision matrices, when navigating trade-offs and ethical dilemmas. Embedding real-world case studies [18, 19] or simulated design challenges [20] that emphasize societal impacts and sustainability could deepen students' understanding of these critical elements. Providing tools like decision matrices or empathy maps [21] early in the course may also support students in tackling complex problems navigating trade-offs.

- **Foster collaboration and creativity through targeted activities:** The theme of *Expansive Thinking* highlights the importance of peer review or collaborative assignments where students critique and refine each other's designs based on stakeholder feedback. Collaborative learning experiences in online courses have been shown to deepen learning, enhance critical thinking skills, and cultivate teamwork while fostering a strong sense of belonging [22, 23]. Reflections on teamwork specifically prompting how diverse perspectives helped improve their design may help broaden students' understanding of value creation.

- **Link course content to tangible, real-world applications:** Reflections within the *Utility Value* theme showcase the importance of industry relevance. Expanding the scope of online projects to include industry-relevant challenges or partnerships could enhance students' career readiness [24, 25]. For example, opportunities to pitch project ideas to external stakeholders (industry or community partners) may provide valuable context, motivation, and be yet another approach to strengthen students' values thinking.

- **Adapting for Other Engineering Programs and Modalities:** These findings suggest that similar challenges may emerge in other courses and across modalities.

- **In-person settings.** In-person courses could leverage live stakeholder engagement, such as inviting industry professionals or community members to provide real-time feedback on student projects to improve *Utility Value*. Facilitated discussions and in-class decision-making exercises using structured tools like decision matrices or empathy maps (as mentioned in *Grappling)* could enhance students' ability to navigate complex trade-offs in a collaborative setting.
- **Other online courses.** Online courses could incorporate more scaffolded, low-stakes activities to help students engage with value creation in smaller, more manageable steps before the final project, especially considering *Time Constraints and Prioritization*. Embedding structured peer review sessions where students assess each other's design decisions from a value creation perspective could enhance their ability to think critically about societal and economic impacts.
- **Other Engineering disciplines.** While this study focused on an Introduction to Engineering course, the integration of EML principles is highly relevant to other engineering disciplines. Biomedical engineering courses could incorporate stakeholder interviews with healthcare professionals; software engineering courses could explore value creation through user experience (UX) research and ethical AI considerations. Across disciplines, courses can adopt real-world case studies and customer discovery to reinforce EM and value creation.

As the demands on engineers continue to evolve, integrating EML principles remains a promising strategy for equipping students with the tools to create meaningful and sustainable value in their careers and communities.

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Appendix A. Pre-survey and Post-survey EM-related items

SELF-REPORT SURVEYS

PART I: EM

Please rate your ability to perform the following tasks on a scale of No ability to Outstanding ability.

Scale: 0 to 4 - No ability, minimal ability, basic ability, adequate ability, outstanding ability

1. Define entrepreneurial mindset (EM)
2. Define entrepreneurially minded learning (EML).
3. Identify the 3C's of EML.
4. Apply the 3C's of EML in future education/career

PART II: Creating Value (Eng Design)

How well do you think the following statements describe you? Rate on a scale of 1 = Does not describe me at all, 2 = Barely describes me, 3 = Somewhat describes me, 4 = Neutral, 5 = Generally describes me, 6 = Mostly describes me, 7 = Completely describes me.

1. I value teamwork with diverse perspectives.
2. I think about the benefits and drawbacks of a market-based view of value.
3. I gather data to support ideas.
4. I gather data to refute ideas.
5. I regularly ask questions that reveal authentic demand.
6. I usually test new ideas with others to obtain feedback before finalizing.
7. I explore multiple solution paths to a given problem.
8. I evaluate solutions considering individuals versus society.

PART III: Creating Value (Attitude and Approaches)

How well do you think the following statements describe you? Rate on a scale of 1 = Does not describe me at all, 2 = Barely describes me, 3 = Somewhat describes me, 4 = Neutral, 5 = Generally describes me, 6 = Mostly describes me, 7 = Completely describes me.

1. I critically observe surroundings to recognize opportunity.
2. I am willing to modify an idea/product based on feedback.
3. I believe in learning from failures to improve a solution.
4. I seek out opportunities to determine what is valuable to others.
5. The idea of tackling society's biggest problems motivates me.
6. I spend time thinking about what engineering solutions are good for individuals versus society.
7. I spend time thinking about how the value of my work is connected to human flourishing and well-being.

8. I believe in reframing problems as opportunities.
9. Understanding the greater value behind an idea is important for me.
10. I am willing to change directions on a project after putting forth a lot of effort.
11. It is important for me to do things that provide a potential economic, social, or environmental value.
12. I see the value in using the Entrepreneurial Mindset concepts in my future education and/or career.