Exploring Lunar Innovation to Support Entrepreneurial-Minded Learning

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Abstract

Engineering education often emphasizes structured problem-solving and well-defined procedures, which can limit students' ability to operate effectively under ambiguity and constraint. Traditional project experiences, typically grounded in familiar, Earth-based contexts, rarely expose students to the uncertainty and systems-level complexity characteristic of real-world innovation. To address this gap, this study implemented a semester-long lunar construction project within an undergraduate Construction Project Management course. Students assumed the role of design-build contractors tasked with developing feasible solutions to lunar construction challenges, including dust mitigation, radiation shielding, and thermal control. The project was intentionally designed to operationalize the entrepreneurial mindset through the Curiosity, Connections, and Creating Value framework. Student outcomes were examined using a mixed-methods approach, combining pre–post self-reported confidence surveys (n = 15), rubric-based evaluation of project deliverables, and thematic analysis of written reflections. Quantitative results revealed statistically significant gains across all measured outcomes, with large effect sizes observed for applying engineering knowledge to unfamiliar contexts, using project management tools, developing solutions under uncertainty, and reasoning about tradeoffs. Qualitative findings indicated increased exploratory thinking, systems-level integration, and value-oriented decision-making. Together, the results suggest that frontier engineering contexts such as lunar construction can serve as effective platforms for supporting confidence and behaviors aligned with entrepreneurial-minded learning within core engineering coursework. The semester-long project was implemented in a required undergraduate Construction Project Management course enrolling 18 students. By embedding ambiguity, constraint, and feasibility-driven reasoning into required technical deliverables, the project supported both technical learning and confidence aligned with entrepreneurial mindset dimensions without reducing disciplinary rigor.

1.0 Introduction

Engineering education has traditionally excelled at teaching structured problem-solving techniques, providing students with well-defined problems and procedures. However, an overemphasis on highly structured problems can create *"detrimental epistemological biases"* in engineers, limiting their ability to tackle complex or ill-structured challenges in practice [1]. Real-world engineering problems are often ambiguous and constrained by uncertainty, requiring creativity and adaptation beyond the textbook methods. Scholars have noted that *"the successful future strategists will exploit an entrepreneurial mindset… the ability to rapidly sense, act, and mobilize, even under uncertain conditions"* [2]. This concept of an entrepreneurial mindset (EM) has gained prominence as a key attribute for engineers facing the open-ended problems of the 21st century. In essence, an entrepreneurial mindset equips engineers to be dynamic, opportunity-oriented problem solvers who thrive amidst ambiguity and constraints. Embedding this mindset in undergraduate engineering curricula is increasingly seen as crucial for producing innovative engineers who can navigate complexity and create impactful solutions [3]. Indeed, prior studies have linked entrepreneurship-related education to improved employability and innovation skills in STEM graduates, highlighting the value of supporting entrepreneurial-minded learning in future engineers.

In response to this need, our work explores a novel approach to promote an entrepreneurial mindset within an engineering program by immersing students in a futuristic lunar engineering challenge. This context was chosen to intentionally push students beyond familiar, Earth-bound problems and engage them with the kinds of uncertainty, extreme conditions, and systems-level complexity that characterize emerging technological frontiers. The timing of this initiative is apt: global space agencies and companies are entering a new era of lunar exploration and development. NASA's Artemis program, for example, aims to establish a sustainable base camp on the Moon's south pole in the coming years [4]. Alongside Artemis, other nations and private firms have unveiled plans for lunar habitats, infrastructure, and resource utilization, recognizing the Moon as a stepping stone for Mars and beyond. These ambitions have elevated lunar construction and infrastructure from science fiction to an imminent engineering reality. A recent review noted that multiple agencies have *"developed mid-to-long-term plans for lunar habitation, including the construction of lunar infrastructure,"* and it explicitly calls for greater involvement of civil engineering expertise in *"deep space endeavors."* [4]. In this context, engaging students with lunar engineering problems serves a dual purpose: it aligns engineering education with cutting-edge industry developments, and it provides an authentic sandbox for students to practice innovation under novel constraints. By working on lunar design-build problems (e.g. dust mitigation, radiation shielding, thermal control), students must confront issues of extreme environments and resource limitations similar to those facing real lunar engineers. This experience is intended to cultivate a forward-thinking, opportunity-driven mindset. Instead of following step-by-step lab exercises, students assume the role of pioneers solving open-ended problems – much like entrepreneurs approaching a new market opportunity. We hypothesize that such an experience can increase students' curiosity, resilience, and ability to "think outside the box," better preparing them to lead innovation in rapidly advancing technological domains on Earth and beyond.

This paper introduces the lunar innovation project implemented in an undergraduate engineering course and examines its impact on students' entrepreneurial mindset. The project design was grounded in the Kern Entrepreneurial Engineering Network (KEEN) framework of Curiosity, Connections, and Creating Value, as articulated by the Engineering Unleashed initiative [3]. Students were challenged to demonstrate curiosity by asking probing questions about unfamiliar lunar conditions, to make connections by integrating knowledge across disciplines and considering diverse stakeholder needs, and to create value by developing solutions with tangible benefits under realistic constraints. Throughout the project, we emphasized not only technical feasibility but also the broader purpose and impact of the solutions – mirroring how entrepreneurial engineers must articulate the value of their innovations. In the following sections, we provide background on the entrepreneurial mindset in engineering education and describe how the lunar project was structured to embed entrepreneurial-minded learning. We then discuss the outcomes of this approach, including qualitative and quantitative evidence of gains in student confidence, adaptability, and creative problem-solving abilities. By situating an educational experience at the nexus of engineering, entrepreneurship, and space technology, this work suggests a novel strategy for producing engineers who can envision and build for future industries both on and beyond Earth.

2.0 Background

2.1 Entrepreneurial Mindset in Engineering Education

There is growing recognition that engineers need more than strong analytical skills – they need a mindset oriented toward innovation, value creation, and adaptability. The entrepreneurial mindset (EM) is commonly described as a set of cognitive skills and attitudes that enable individuals to identify opportunities, make connections, and persistently create value, even in uncertain circumstances. Rather than being limited to business startups, an entrepreneurial mindset in engineering is about how one approaches any problem or project. Bekki *et al.* put it succinctly as the *"cognitive behaviors that orient an engineer toward opportunity recognition and value creation in any context, not just that of an entrepreneurial venture." [3]*. In practice, this means an engineer with an EM will habitually question the status quo (showing curiosity), synthesize information from many sources (making connections), and focus on the impact or benefit of their work (creating value). These three dimensions – curiosity, connections, and creating value – are often referred to as the "3 Cs" of the entrepreneurial mindset. This study does not claim to measure the entrepreneurial mindset in its entirety; rather, it examines changes in confidence and reasoning behaviors aligned with selected entrepreneurial mindset dimensions. They were popularized by the KEEN network and have become a convenient framework for educators to design curriculum and learning outcomes around entrepreneurial thinking. For example, London *et al.* (2018) operationalized the 3Cs framework by identifying a set of 12 student attitudes and 17 behaviors associated with curiosity, making connections, and creating value in engineering contexts (e.g. demonstrating persistent curiosity beyond coursework, integrating information across fields, and evaluating societal benefits of solutions) [5]. Such frameworks provide a language for instructors to explicitly target mindset development in their courses.

It is important to note that the entrepreneurial mindset extends beyond just doing "entrepreneurship projects" – it is about nurturing certain habits of mind. Prior research in engineering education has shown that simply adding design projects or business elements does not guarantee an entrepreneurial mindset; the *way* students engage and reflect is crucial. Educators are therefore increasingly focused on pedagogies and assessments that truly cultivate and measure mindset growth, rather than just teaching business plan basics. Tools have been developed to capture students' perceptions of their own entrepreneurial mindset (for instance, through surveys, reflection prompts, or concept map assessments) [6]. Zappe (2018) emphasizes avoiding *"construct confusion"* by clearly defining what aspects of mindset are being developed and assessed [3]. In our implementation, we targeted mindset outcomes directly: student reflections and survey instruments were used to gauge changes in curiosity (e.g. did students ask more questions and explore beyond the given material?), connections (did they link different knowledge domains and consider system-level implications?), and value creation (could they articulate the potential impact and feasibility of their solutions?). By aligning our evaluation methods with the 3Cs, we aimed to ensure that we were assessing shifts in confidence and reasoning behaviors aligned with the 3Cs, not just completion of an open-ended assignment. This focus responds to calls in the community to assess entrepreneurial mindset development itself, rather than proxy metrics, thereby adding rigor to increases in self-reported confidence.

Another facet of the entrepreneurial mindset is its strong overlap with what employers seek in engineering graduates. Surveys of industry indicate that traits such as initiative, adaptability, creativity, and business acumen are highly valued competencies in addition to technical knowledge [7]. O'Leary (2012) found that exposure to entrepreneurship education in college had a positive impact on the employability of science and engineering graduates, as it cultivated skills like opportunity recognition and effective communication that translated to the workplace [8]. Likewise, Duval-Couetil *et al.* (2012) reported that engineering students who engaged in entrepreneurship programs showed higher interest in innovation and greater self-efficacy in professional skills compared to their peers. These findings reinforce the argument that advancing an entrepreneurial mindset is not ancillary to engineering training but rather integral to producing well-rounded engineers prepared for modern careers. In light of this, many engineering programs (often with support from initiatives like KEEN and VentureWell) have been integrating entrepreneurial mindset learning (EML) modules, from first-year cornerstone courses to senior design projects. The approach typically involves active, student-centered learning experiences that prompt students to practice curiosity, make interdisciplinary connections, and consider the broader value of their engineering work. Our study builds on this growing movement by applying the EML philosophy in a new domain – lunar construction – thereby expanding the repertoire of contexts in which EM can be cultivated.

2.2 Lunar Innovation as a Learning Context

Choosing the Moon as the context for an engineering project was a deliberate strategy to immerse students in a futuristic, high-uncertainty problem space. The lunar environment presents extreme engineering challenges that are far outside students' prior experiences: for instance, the lack of atmosphere and magnetic field means intense solar and cosmic radiation; the lunar day/night cycle causes two-week long nights with drastic temperature swings from +120°C to –170°C; and the regolith (moon dust) is abrasive, electrostatically clingy, and pervasive [4]. These conditions make nearly every aspect of construction and habitation on the Moon difficult. As Xia *et al.* (2025) summarize, building infrastructure on the Moon *"requires overcoming bottlenecks in materials science, manufacturing processes, and intelligent equipment"* due to the high vacuum, microgravity, harsh thermal fluctuations, and abrasive dust [4]. In our course project, students grappled with three representative lunar construction challenges: dust mitigation, radiation shielding, and thermal control for a lunar surface structure. Each of these topics is actively researched by NASA and others, with no simple textbook solutions – exactly the kind of ambiguous problem that spurs innovative thinking. By confronting these challenges, students had to engage in genuine problem definition (What *are* the needs and constraints in a lunar base? Who are the stakeholders and what do they value – e.g. astronaut safety, cost, reliability?), and then generate creative approaches drawn from first principles and cross-disciplinary knowledge. For example, in addressing dust mitigation, teams explored ideas ranging from electrostatic dust repellent coatings to mechanical sweeper robots, comparing their feasibility under lunar gravity and vacuum. In doing so, they connected principles of physics, materials science, and even aerospace engineering – making the "connections" that bridge their siloed coursework into an integrated solution. Similarly, for radiation protection, students weighed different regolith-based shielding concepts versus novel materials, evaluating trade-offs in weight, deployment, and habitability (thus practicing value-focused judgment). The curiosity component was constantly invoked, as students had to ask unfamiliar questions: How does concrete cure in vacuum? What novel cooling systems might work during the 14-day lunar night? Encouraging this inquisitiveness was key – rather than giving them answers, instructors provided resources (such as NASA technical papers or Artemis mission concept documents) and challenged teams to learn as they went.

The lunar project was implemented in an upper-level *Construction Management in Engineering* course as a semester-long design-build simulation. Students were essentially placed in the role of entrepreneurial design-build contractors in the year 2035, bidding on a contract to develop portions of a lunar base. This role-play element reinforced an opportunity-driven perspective: much like a startup company identifies a market gap, student teams had to identify and justify a particular approach that would add value to a lunar mission (e.g. a novel construction method that saves time or a technology that improves astronaut safety). The project unfolded in stages that mirror an entrepreneurial process. In the ideation phase, teams brainstormed multiple concepts for each technical problem, spurred by curiosity and unconstrained thinking. They had to research emerging technologies (such as autonomous robots or in-situ resource utilization techniques) and draw connections to the lunar use-case, thereby practicing *transfer of knowledge to a new context*. Next, during the concept development phase, they narrowed down ideas by considering stakeholder needs and system integration – making *connections* to broader system requirements (for instance, how a dust mitigation system interacts with solar panels or how a radiation shield might affect habitat design). Here the "connections" mindset also involved collaboration: students consulted with faculty from different disciplines and even industry mentors, learning to network knowledge like entrepreneurs tapping advisors. Finally, in the value proposition phase, each team prepared a proposal arguing how their solution created value: they had to articulate benefits (e.g. increased reliability, reduced cost, enhanced sustainability), address feasibility concerns, and compare against potential alternatives. This required them to *step into the shoes of stakeholders* (NASA engineers, astronauts, investors) and communicate why their innovation matters – a direct exercise in creating value and pitching an idea's merit.

Throughout the project, instructional scaffolding was minimal by design. Unlike typical course projects with step-by-step guidelines, this lunar challenge presented an open frontier where students had to define the problem parameters and success criteria in tandem with developing the solution. This pedagogical choice was aimed at developing students' tolerance for ambiguity and their creative confidence. Research shows that when students engage with authentically ill-structured problems, they experience initial uncertainty but eventually demonstrate growth in higher-order thinking and teamwork skills [9]. Consistent with this, our students initially found the lunar project daunting – many had never taken a course in aerospace or planetary science – but this triggered a high level of *intellectual curiosity*. Class discussions shifted from simply "What is the correct answer?" to "What do we need to learn to solve this?" – a hallmark of entrepreneurial learning. We also observed that giving students the identity of design-build contractors added *authenticity* and motivation. Instead of a contrived homework, they felt responsible to come up with a credible plan as if presenting to a client (in fact, the final presentations were juried by a panel including an engineer involved in NASA's lunar projects). This authentic role-playing aligns with best practices in entrepreneurial education, where students benefit from *acting as entrepreneurs* in context rather than merely learning about entrepreneurship in theory.

By integrating the lunar challenge into the curriculum in this way, we aimed to make entrepreneurial mindset development an implicit outcome of doing engineering, not an extra-curricular add-on. Students were not *told* "this is entrepreneurship;" instead, through the process they naturally practiced entrepreneurial behaviors: they coped with missing information, they iterated designs after critical feedback, they considered the scalability and impact of their ideas, and they communicated the *value* of their solution to a diverse audience. These are precisely the mindset and skillset elements that organizations like KEEN champion for engineer entrepreneurs [10][11][12]. Furthermore, using a sustainability-oriented, futuristic context like lunar development helped students see the *larger purpose* of engineering innovation. Many commented in reflections that working on a Moon project expanded their perspective on what engineering could achieve for society and *"made me more excited to solve big problems."* This suggests that *curiosity and vision* – key ingredients of the entrepreneurial mindset – can be effectively sparked by learning experiences that look beyond immediate, familiar applications [13][14][15].

In summary, the background rationale for our approach draws from multiple converging trends: the need for engineers who can innovate under uncertainty, the established benefits of entrepreneurial mindset education in cultivating such capabilities, and the timely emergence of lunar exploration as a grand engineering challenge that can inspire and educate. By situating a construction management course project on the Moon, we create a platform to simultaneously teach core engineering concepts and entrepreneurial thinking. The following sections will detail the implementation and outcomes of this project, examining how students' mindsets shifted and what insights were gained about teaching the entrepreneurial mindset through a lunar innovation lens.

3.0 Methodology

3.1 Course context and participants

The study was conducted in a single undergraduate Construction Project Management course offered during the Fall 2025 semester. The intervention spanned the full 15-week semester. The course enrolled 18 students, all of whom completed the lunar construction project as part of the regular course requirements. The project was embedded within the course curriculum and replaced a traditional project management assignment. Participation in the surveys and reflections was voluntary and used solely for educational research purposes. This study is reported as a work-in-progress implementation. Of the enrolled students, 15 provided complete matched pre- and post-survey responses and were included in the quantitative analysis.

3.2 Project design and instructional intervention

Students participated in a semester-long lunar construction project designed to simulate a high-uncertainty, constraint-driven engineering context. Students assumed the role of design-build contractors tasked with developing feasible solutions to construction challenges associated with lunar environments, such as dust mitigation, material selection, thermal considerations, and infrastructure constructability. The project required students to apply core construction project management concepts, including scope definition, scheduling, sequencing, and cost estimation, while adapting these tools to an unfamiliar and extreme setting.

The project emphasized the development of solutions that balanced innovation with feasibility. Students were required to justify design decisions, identify tradeoffs among cost, safety, constructability, and performance, and articulate the broader implications of their solutions. Deliverables included a written technical report, a project management plan incorporating Critical Path Method (CPM) scheduling, and prototype documentation used to communicate design intent. Deliverables were evaluated using an analytic rubric assessing technical feasibility, application of project management tools, tradeoff reasoning, systems integration, and clarity of technical communication. Each criterion was scored on a five-point scale aligned with course learning objectives.

3.3 Data collection instruments

Student outcomes were assessed using three data sources.

First, a pre- and post-project self-reported confidence survey was administered to measure changes in students' confidence across eight outcome areas mapped to course learning objectives and the Curiosity, Connections, and Creating Value dimensions. Survey items were measured on a five-point Likert scale ranging from 1 (Not at all confident) to 5 (Extremely confident). The pre-survey was administered prior to the start of the project, and the post-survey was administered after completion of all project deliverables. Second, students completed post-project written reflections in which they were asked to describe key lessons learned and insights gained from the project. These reflections provided qualitative evidence of how students perceived the learning experience and how they interpreted the challenges and outcomes associated with the lunar construction context.

The confidence survey was a course-specific instrument developed by the instructor to align directly with course learning objectives and targeted entrepreneurial mindset dimensions. Survey items were informed by prior entrepreneurial mindset assessment literature and reviewed by two engineering faculty for face validity. The instrument was not previously validated and is intended to support context-specific interpretation of confidence changes in this work-in-progress study.

3.4 Data analysis

Quantitative survey data were analyzed using paired-samples t-tests to compare pre- and post-project confidence scores for each survey item. Analyses were conducted using only matched responses ($n = 15$). Qualitative reflection responses were analyzed using thematic analysis. Reflections were reviewed iteratively to identify recurring patterns related to students' perceptions of project management practice, application of engineering knowledge to unfamiliar contexts, tradeoff reasoning, and communication of technical ideas. Themes were refined through repeated review to capture dominant patterns across responses. Representative quotes were selected to illustrate each theme while maintaining student anonymity.

4.0 Results

4.1 Quantitative outcomes

Quantitative outcomes were examined using paired pre–post self-reported confidence survey responses collected from students enrolled in a Construction Project Management course. Of the 18 students enrolled, 15 provided complete matched pre- and post-survey responses and were included in the analysis (n = 15; df = 14). All survey items were measured on a five-point Likert scale (1 = Not at all confident, 5 = Extremely confident). Paired-samples t-tests were conducted for each outcome to assess changes in student confidence following the lunar construction project.

Across all eight survey items, post-project confidence scores were higher than pre-project scores (Table 1). Pre-project means indicated low to moderate baseline confidence, while post-project means indicated consistently high confidence following completion of the project. A composite confidence score, computed as the mean of all eight items, showed a statistically significant increase from pre to post with a large within-subject effect size ($t(14) = 10.36$, $p < .001$, $d_z = 2.68$).

At the item level, the largest gains were observed in students' confidence in applying civil engineering knowledge to unfamiliar contexts and using project management tools such as the CPM, both of which demonstrated very large effect sizes. Significant increases with large effects were also observed for confidence in developing creative solutions under uncertainty**,** balancing cost, schedule, and safety tradeoffs**,** identifying sustainability and resilience challenges, and drawing connections between engineering decisions and broader societal or environmental impacts. Additional significant gains were observed for technical communication and independent work on industry-mirroring projects.

All pre–post differences were statistically significant ($p < .001$). Complete descriptive statistics, test results, and effect sizes for each outcome are reported in Table 1.

Table 1. Pre–post student confidence outcomes for the lunar construction project.

Outcome	**Pre M (SD)**	**Post M (SD)**	**Mean gain**	***t*(14)**	***p***	d_z
Composite (mean of items a–h)	2.53 (0.58)	4.25 (0.54)	1.72	10.36	< .001	2.68
a) Applying civil engineering knowledge to unfamiliar contexts (e.g., lunar construction)	1.80 (0.77)	4.17 (0.79)	2.37	12.75	< .001	3.29
b) Identifying and addressing sustainability or resilience challenges in construction projects	2.53 (0.99)	4.10 (0.81)	1.57	5.98	< .001	1.54
c) Balancing cost, schedule, and safety tradeoffs in project planning	2.40 (1.18)	3.93 (0.96)	1.53	6.00	< .001	1.55
d) Using project management tools such as the CPM	2.27 (1.10)	4.53 (0.61)	2.27	6.94	< .001	1.79
e) Developing creative solutions under uncertainty with limited resources	2.73 (0.88)	4.27 (0.70)	1.53	7.99	< .001	2.06
f) Communicating technical ideas effectively through reports, presentations, and prototypes	3.00 (1.07)	4.47 (0.61)	1.47	5.63	< .001	1.45
g) Working independently on a project that mirrors real-world industry practices	2.87 (0.74)	4.28 (0.71)	1.42	7.65	< .001	1.97

Outcome	Pre M (SD)	Post M (SD)	Mean gain	$t(14)$	p	d_z
h) Drawing connections between engineering decisions and broader societal or environmental impacts	2.67 (0.62)	4.27 (0.70)	1.60	8.41	< .001	2.17

4.2 Qualitative outcomes

Post-project reflections were analyzed to identify recurring themes related to student learning and perceptions of the lunar construction project. Responses were reviewed holistically and coded for common patterns. Four primary themes emerged.

Theme 1: Reframing project management as a complex, integrative practice
Many students described a shift in how they understood project management, moving beyond a narrow focus on scheduling to a broader appreciation of coordination, responsibility, and decision-making under constraints. Reflections indicated that the project helped students recognize the day-to-day complexity faced by project managers, particularly in high-risk environments. One student noted, *"This experience helped me think differently about project management and really see how much they have to handle on a day-to-day basis."* Another reflected that the project was "satisfying" because it required using "all the necessary skills… when it comes to project management," reinforcing the integrative nature of the discipline.

Theme 2: Applying civil engineering knowledge to extreme or unfamiliar environments
Students frequently emphasized the challenge and value of transferring conventional civil engineering principles to a lunar context. The unfamiliar environment prompted students to question assumptions common in Earth-based projects and adapt their designs accordingly. One reflection stated, *"This experience has helped me think differently about how civil engineering principles can be applied to extreme environments."* Another student highlighted growth in technical areas specific to the context, noting improvements in "CE design under extreme environments" and the consideration of in-situ resource utilization trade-offs.

Theme 3: Tradeoff reasoning, feasibility, and sustainability awareness
A recurring theme across reflections was the need to balance competing considerations such as safety, cost, innovation, and resource limitations. Students described gaining awareness of how design decisions influence feasibility and long-term outcomes. One student wrote, *"Designing a dust mitigation system taught me to balance safety, cost, and innovation while appreciating how small design decisions can impact long-term mission success."* Others connected this reasoning to sustainability, emphasizing that responsible design begins with "smart resource utilization," particularly in constrained environments.

Theme 4: Strengthened fluency with project management tools and technical communication
Students also reflected on increased confidence in using formal project management tools and communicating technical ideas through deliverables and prototypes. Several responses specifically referenced CPM scheduling as a key area of growth. One student noted, *"This project reinforced my knowledge of project planning through the CPM method and provided valuable experience in translating theoretical concepts into tangible models."* Another

emphasized gains in “CPM fluency” and “technical communication through a working prototype,” suggesting that the project context enhanced the perceived relevance of these skills. Figure 1 shows two student sketches of proposed solutions and the corresponding prototypes developed during senior design. These qualitative findings are intended to illustrate early patterns in student reasoning rather than provide exhaustive thematic saturation. Future iterations will incorporate expanded artifact analysis and systematic coding procedures to strengthen qualitative rigor.

Figure 1. Two student sketches of proposed solutions and the resulting prototypes.

4.3 Alignment of qualitative themes with the entrepreneurial mindset framework

The mapping presented here reflects alignment between observed student behaviors and the Curiosity, Connections, and Creating Value dimensions, rather than direct measurement of entrepreneurial mindset as a latent construct. The qualitative themes identified in the reflection analysis align closely with the three dimensions of the entrepreneurial mindset framework: Curiosity, Connections, and Creating Value.

Curiosity was most evident in students’ engagement with unfamiliar and extreme conditions and their willingness to question assumptions embedded in conventional engineering practice. Themes related to applying civil engineering knowledge in a lunar environment demonstrate how the project prompted exploratory thinking and adaptive problem-solving. Students described rethinking how engineering principles function when standard environmental conditions no longer apply, indicating an openness to learning and experimentation in the face of uncertainty.

Connections emerged through students’ recognition of the integrative nature of project management and the interdependence of technical, organizational, and contextual factors. Reflections emphasizing project management complexity and CPM scheduling illustrate how students connected technical tools to broader project systems, including sequencing, coordination, and communication. Students also demonstrated systems-level thinking by linking design decisions to downstream impacts, stakeholder considerations, and implementation challenges.

Creating Value was reflected in students’ emphasis on feasibility, tradeoffs, and sustainability. Themes centered on balancing cost, safety, innovation, and resource constraints highlight students’ growing awareness that engineering solutions must deliver value within real-world limitations. Reflections describing the importance of resource utilization, constructability, and long-term mission success indicate an emerging ability to articulate why certain solutions are viable, responsible, and impactful.

Taken together, the mapping of qualitative themes to the 3Cs suggests that the lunar construction project operationalized entrepreneurial-minded practices not as an abstract framework, but as a set of practices embedded within technical decision-making, planning, and design under constraint.

5.0 Discussion

The findings from this study suggest that embedding a lunar construction challenge within a Construction Project Management course can substantially influence students' confidence and reasoning related to engineering practice under uncertainty. Across all eight measured outcomes, students reported significant increases in confidence following participation in the project, with particularly large gains observed in applying engineering knowledge to unfamiliar contexts and using project management tools such as CPM scheduling. These quantitative shifts are reinforced by qualitative reflections describing changes in how students approached problem framing, tradeoff reasoning, and the integration of technical and managerial considerations.

The magnitude of the observed effect sizes is notably large for self-reported Likert measures. Several factors likely contributed to this inflation, including the small sample size, low pre-intervention confidence levels, repeated engagement with targeted skills throughout the semester, and potential ceiling effects in post-project responses. Accordingly, effect sizes should be interpreted as indicators of substantial perceived growth rather than precise estimates of magnitude.

The largest observed confidence gain was associated with applying civil engineering knowledge to unfamiliar environments. This result is noteworthy given the low baseline confidence reported prior to the project. The lunar context appears to have functioned as a deliberate disruption to routine assumptions, requiring students to transfer knowledge rather than rely on familiar precedents. Reflection data indicate that this unfamiliarity prompted students to think more critically about environmental constraints, material selection, and constructability, supporting the claim that frontier contexts can promote adaptive and exploratory thinking in engineering education.

Importantly, the use of a futuristic or extreme context did not dilute attention to core project management skills. Instead, confidence in using CPM scheduling and other project management tools showed some of the strongest gains. Qualitative responses suggest that the need to justify feasibility and execution in a high-risk environment increased the perceived relevance of planning, sequencing, and coordination. This finding challenges the concern that speculative projects may reduce technical rigor and instead indicates that unfamiliar contexts can heighten the importance of structured decision-making tools.

The results also indicate growth in students' ability to balance competing constraints, including cost, safety, sustainability, and innovation. Both survey outcomes and reflection themes point to increased awareness of tradeoffs and feasibility considerations, which are central to value-oriented engineering practice. Students' emphasis on resource utilization, long-term impacts, and mission success suggests that the project supported the development of reasoning aligned with the Creating Value dimension of the entrepreneurial mindset framework. When considered collectively, the quantitative and qualitative findings indicate alignment with the three dimensions of the entrepreneurial mindset. Curiosity was reflected in students' engagement with unfamiliar conditions and willingness to rethink assumptions. Connections emerged through students' recognition of how technical decisions, project management tools, and broader system impacts interact. Creating Value was evident in students' focus on feasibility, tradeoffs, and the justification of design choices within constraints. Notably, these dimensions were not introduced as abstract concepts but were embedded within required deliverables and decision-making processes.

Several limitations should be acknowledged. The study was conducted in a single course with a small sample size and no comparison group. The confidence survey was course-specific and not externally validated. Rubric-based assessment of project deliverables was conducted by a single instructor, and inter-rater reliability was not established. In addition, quantitative outcomes rely on self-reported confidence measures rather than direct or longitudinal performance comparisons, and ceiling effects observed in post-project responses suggest that more sensitive instruments may be needed to capture growth at higher confidence levels. These limitations constrain generalizability and causal inference but are appropriate for a work-in-progress study intended to examine early patterns in student confidence and reasoning aligned with entrepreneurial-minded learning.

6.0 Conclusion

This study examined the impact of a lunar construction project embedded within a Construction Project Management course on student confidence and learning related to engineering practice under uncertainty. Using a mixed-methods approach, the study found significant increases in student self-reported confidence across all measured outcomes, including applying engineering knowledge to unfamiliar contexts, using project management tools, balancing tradeoffs, and communicating technical ideas. Qualitative reflections further revealed shifts in how students perceived project management practice, engaged with extreme design constraints, and reasoned about feasibility and sustainability.

The findings suggest that situating project management instruction within a frontier engineering context can promote adaptive thinking without sacrificing technical rigor. The lunar construction project required students to integrate planning tools, design reasoning, and value-based decision-making in a setting where assumptions common to Earth-based projects were no longer valid. As a result, students developed greater confidence in transferring knowledge, evaluating tradeoffs, and articulating the value of their solutions.

Although the study was limited to a single course and relied in part on self-reported measures, the convergence of quantitative gains and qualitative evidence indicates that high-ambiguity, constraint-driven projects can serve as effective platforms for cultivating entrepreneurial-minded engineers. Future work will incorporate validated entrepreneurial mindset instruments, longitudinal assessment, and broader multi-course implementation to strengthen causal inference and examine the persistence of confidence and reasoning gains beyond a single course offering.

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