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Community-Based Design Challenges to Foster Entrepreneurial Mindset: A Case Study on Energy Resilience and Industry Collaboration in an Undergraduate Design Course

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Abstract
This paper presents a pilot study examining the integration of community- and industry-partnered Project-Based Learning (PjBL) into ME-340: Design Methodology in Fall 2025. Supported by a Leonhard Center Grant for Entrepreneurial Mindset Student Success (GEMSS), the intervention engaged undergraduate mechanical engineering students in authentic, externally proposed engineering design challenges mentored by local partners. Two projects were implemented in collaboration with the Monroe County Conservation District (MCCD) and Verdantas Engineering, addressing renewable energy resilience and industrial waste-heat recovery, respectively. The paper describes the pedagogical framework, course redesign, project structure, assessment instruments, and analytic rubric used to evaluate student performance. Learning outcomes were aligned with ABET Student Outcomes SO2 (Engineering Design), SO3 (Communication), and SO5 (Teamwork), as well as KEEN's entrepreneurial mindset framework (Curiosity, Connections, Creating Value). Descriptive performance data and rubric distributions are presented to support claims regarding student attainment. Results suggest that externally mentored design challenges can be systematically integrated into a required undergraduate design course while maintaining technical rigor and strengthening stakeholder awareness, professional communication, and value-driven decision making.

1. Introduction

In addition to technical competence, engineers must demonstrate strong communication, teamwork, leadership, and project management skills, while remaining attentive to ethical, economic, social, and cultural considerations. These expectations have placed pressure on universities to graduate engineers who are not only technically prepared but also adaptable, innovative, and ready to contribute effectively to professional practice. Consequently, engineering programs worldwide are re-examining traditional curricula and instructional models to better align with current societal and industry needs. In fact, traditional classroom-based design problems, while effective for introducing structured design methodologies, often lack the ambiguity, contextual constraints, and accountability inherent in real-world engineering work.

A growing body of engineering education research further indicates that student-centered, active learning approaches are more effective than traditional lecture-based instruction in developing these broader competencies. In particular, Project-Based Learning (PjBL) and Problem-Based Learning have been shown to promote deeper learning, creativity, curiosity, and entrepreneurial thinking, while also improving student motivation and engagement [1, 2]. By emphasizing hands-on work, real-world problem contexts, and collaborative learning, PjBL shifts the educational focus from passive knowledge transmission to active knowledge construction [3]. These approaches have also been associated with increased student persistence and reduced dropout rates, especially in rigorous engineering programs. At the same time, national initiatives such as the Kern Entrepreneurial Engineering Network (KEEN) have highlighted the importance of cultivating an entrepreneurial mindset in engineering students.

PjBL has been extensively studied in engineering education over the past two decades. Unlike Problem-Based Learning, which typically centers on guided inquiry around a defined problem, PjBL emphasizes extended, structured design work culminating in a tangible deliverable and often involving authentic stakeholders. Prior studies have demonstrated the effectiveness of PjBL across a range of engineering contexts. For example, a first-year engineering course focused on prototyping, fabrication, and testing showed that PjBL can support both foundational and advanced manufacturing skill development [4]. Similarly, a study showed that PjBL can integrate statistical design of experiments (DOE) with advanced manufacturing technologies, such as additive manufacturing. In that implementation, 51 students worked in teams in a semi-industrial environment, applying theoretical concepts through hands-on experimentation. The results indicated strong student performance in technical competencies as well as increased motivation and engagement, highlighting the effectiveness of PjBL in bridging theory and practice [5]. Recent work has also explored more flexible, student-centered variations of PjBL in foundational engineering courses. In a study conducted in the context of Engineering Mechanics (Statics and Dynamics), an open-ended, opt-in PjBL intervention was introduced as a supplement to traditional exams. Students were allowed to define their own project topics based on real-world scenarios, and participation was voluntary. Results indicated that participating students demonstrated higher exam performance compared to earlier assessments. Notably, the intervention was particularly beneficial for lower-performing students, with higher participation and performance gains among female students. These findings suggest that flexible, student-driven PjBL structures can enhance inclusivity, support diverse learning strategies, and improve overall learning outcomes, even in traditionally theory-intensive courses such as engineering mechanics [6].

In this context, community-based and industry-partnered design challenges have emerged as a natural extension of PjBL. These approaches give students opportunities to engage directly with real stakeholders, constraints, and uncertainties, grounding engineering design in authentic societal and professional contexts. Such experiences not only reinforce technical competencies but also strengthen students' professional identity, accountability, and understanding of value creation in engineering practice. This paper presents a pilot implementation of community- and industry-driven PjBL in a junior-level mechanical engineering design course. The study focuses on the integration framework, assessment methodology, and descriptive performance outcomes aligned with ABET student outcomes and entrepreneurial mindset development.

2. Course context and pedagogical framework

Motivated by the pedagogical and institutional priorities outlined in Section 1, this study documents the development and implementation of a community-driven innovation challenge framework within **ME-340: Design Methodology**, a required junior-level mechanical engineering course at The Pennsylvania State University, Scranton campus. Prior to Fall 2025, ME-340 employed internally generated design problems developed by the instructor. These projects were technically valuable but largely hypothetical in nature and did not involve external stakeholders. Students worked in teams to develop conceptual designs based on predefined specifications, and the assessment focused primarily on technical documentation and adherence to the engineering design process. While these activities supported ABET Student Outcomes SO2 (Engineering Design) and SO5 (Teamwork), they did not require stakeholder negotiation, regulatory interpretation, or real-time professional communication.

In Fall 2025, the course was redesigned to replace these internally generated problems with externally proposed design challenges sourced from the community and industry partners. The primary structural shift involved integrating real clients, iterative stakeholder feedback, and public-facing final deliverables. This transformation was intended to introduce authentic engineering constraints and enhance student engagement with real-world problem contexts. The initiative was supported by a Leonhard Center Grant for Entrepreneurial Mindset Student Success (GEMSS) and piloted through partnerships with two external organizations: the Monroe County Conservation District (MCCD) and Verdantas Engineering. The resulting design challenges focused on energy resilience and industrial system optimization, requiring students to address open-ended engineering problems while considering technical feasibility, economic viability, environmental impact, and stakeholder needs. All participating students were mechanical engineering majors enrolled in ME-340. While the teams were not multidisciplinary in terms of academic background, students were organized into two primary project teams, each subdivided into functional groups (e.g., technical analysis, systems integration, and economic or feasibility assessment). This structure enabled role differentiation and collaboration across multiple aspects of the design process. The pedagogical framework guiding this implementation was based on three core principles:

1. **Authenticity:** Projects were derived from real operational challenges faced by partner organizations, requiring students to work with incomplete information and evolving constraints.
2. **Stakeholder Engagement:** Students interacted regularly with external mentors to clarify requirements, validate assumptions, and refine proposed solutions.
3. **Entrepreneurial Mindset Development:** Project activities emphasized curiosity, connection-making, and value creation, aligning with KEEN principles rather than focusing solely on narrowly optimized technical solutions.

Faculty oversight emphasized facilitation of the design process, including guidance on problem definition, modeling, and decision-making, while external partners served as domain experts and project clients. This dual-mentorship model provided both academic structure and professional relevance. The central research question guiding this work is:

How can community- and industry-driven design challenges be systematically integrated into a core undergraduate engineering design course to enhance entrepreneurial mindset development and professional readiness? By presenting this pilot implementation, the study aims to contribute practical insights into the design, execution, and educational value of community- and industry-partnered Project-Based Learning frameworks within required engineering curricula. The implementation and its outcomes were evaluated using the assessment framework described in Section 5.

3. Case Studies: Community- and Industry-Driven Design Challenges in ME-340

To examine the effectiveness of community-based and industry-partnered Project-Based Learning (PjBL) in fostering an entrepreneurial mindset and professional readiness, two distinct but structurally aligned design challenges were implemented in ME-340: Design Methodology during the Fall 2025 semester. The first project was conducted in partnership with the Monroe County Conservation District (MCCD) and focused on energy resilience for a public-sector facility. The second project, developed in collaboration with Verdantas Engineering, addressed waste heat recovery in industrial manufacturing systems. Together, these projects provided complementary learning environments that exposed students to both community-driven and industry-driven engineering problems while maintaining a consistent pedagogical framework, team structure, and assessment approach.

Table 1. Community-Based Design Activities for the MCCD Energy Resilience Project

Timeframe	Activity	Participants	Instructional Purpose
Aug. 26–28, 2025	Project scoping and coordination	Instructor; MCCD engineer; MCCD staff	Define project objectives and alignment with ME-340 learning outcomes
Sept. 5, 2025	Kickoff meeting and site visit	MCCD engineer; instructor; student teams	Introduce real-world constraints and stakeholder expectations
Sept. 5–26, 2025	Initial research and conceptual design	Student teams	Perform preliminary system sizing and develop conceptual solar–battery layouts
Sept. 18–22, 2025	Industry Q&A and data exchange	Students; MCCD engineer; contractors	Practice professional communication and gather technical data
Sept. 23–26, 2025	Deliverable 1 submission	Student teams; MCCD engineer	Translate analysis into professional documentation and receive feedback
Sept. 29–Oct. 20, 2025	Building code and regulatory research	Student teams	Incorporate standards and permitting constraints into design decisions
Oct. 21–22, 2025	Technical review meeting	Students; MCCD engineer; instructor	Refine system architecture based on stakeholder input
Oct. 22–Nov. 14, 2025	Cost estimation and system integration	Student teams	Assess economic feasibility and value creation
Nov. 26, 2025	Final technical report	Student teams	Synthesize stakeholder considerations
Dec. 11, 2025	Final presentation to MCCD Board	Students; MCCD Board; instructor	Communicate recommendations to non-technical stakeholders

Case Study 1: Community-Based Energy Resilience Project with MCCD
The MCCD project tasked student teams with developing a conceptual solar–battery backup system capable of maintaining critical building operations during extended power outages. Students were required to analyze facility energy usage, assess roof geometry and electrical service characteristics, evaluate battery storage requirements, and estimate system costs. This project emphasized stakeholder engagement, regulatory compliance, and value-driven decision-making appropriate for a public-sector organization focused on conservation and community resilience. Throughout the semester, students interacted directly with MCCD engineers, external contractors, and facilities personnel through structured meetings and professional communication. These interactions required students to gather incomplete or evolving data, clarify assumptions, and iteratively refine their designs based on stakeholder feedback. As a result, students were exposed to realistic engineering constraints and accountability mechanisms not typically present in classroom-based projects. The project timeline and associated instructional activities are summarized in Table 1.

Case Study 2: Industry-Partnered Waste Heat Recovery Project with Verdantas Engineering

The second design challenge was conducted in collaboration with Verdantas Engineering, a multidisciplinary consulting firm specializing in energy optimization and industrial sustainability. In this project, student teams investigated feasible waste heat recovery strategies for industrial manufacturing systems, using a representative glass furnace as a model application. Students identified waste heat sources, quantified available thermal energy, and evaluated multiple recovery technologies, including batch preheating systems, shell-and-tube heat exchangers, and Organic Rankine Cycle (ORC) systems. Rather than prescribing a single solution pathway, the industry partner emphasized open-ended exploration and required students to conduct trade studies and justify design decisions based on efficiency, safety, installation complexity, maintenance considerations, and return on investment. This project placed a stronger emphasis on quantitative analysis, system modeling, and comparative evaluation of alternatives, reflecting the expectations of industrial engineering practice. Regular technical discussions with the industry mentor provided students with professional feedback and required them to defend assumptions and analytical approaches in a realistic consulting context. The structured progression of activities, stakeholder interactions, and instructional objectives for this project are summarized in Table 2.

Table 2. Industry-Partnered Design Activities for the Verdantas Waste Heat Recovery Project

Timeframe	Activity	Participants	Instructional Purpose
Sept. 10, 2025	Project kickoff meeting	Verdantas engineer; instructor; student teams	Introduce industrial context and project scope
Sept. 10–16, 2025	Process selection and problem framing	Student teams	Identify manufacturing process and waste heat sources
Sept. 16, 2025	Technical Q&A meeting	Students; Verdantas engineer	Clarify furnace geometry, temperatures, and constraints
Sept. 17–29, 2025	Preliminary heat transfer calculations	Student teams	Quantify available waste heat and establish assumptions
Oct. 2, 2025	Submission of preliminary calculations	Student teams; Verdantas engineer	Receive professional feedback
Oct. 2–Nov. 17, 2025	Technology evaluation and trade studies	Student teams	Compare recovery technologies and design alternatives
Nov. 17, 2025	Design review meeting	Students; Verdantas engineer; instructor	Refine designs based on efficiency, safety, and ROI
Nov. 18–Dec. 7, 2025	Cost estimation and ROI analysis	Student teams	Assess economic feasibility and value creation
Dec. 8, 2025	Final presentation and report submission	Students; Verdantas engineer; instructor	Communicate recommendations and justify decisions

While the MCCD project emphasized stakeholder communication, regulatory considerations, and community-focused value creation, the Verdantas project focused more heavily on technical analysis, system optimization, and economic trade-offs. Despite these differences, both projects required students to engage in iterative design, evaluate multiple alternatives, and justify decisions in the presence of real-world constraints, thereby supporting consistent development of ABET-aligned competencies.

4. Comparative Analysis of the Two Projects

The MCCD and Verdantas projects were implemented using a shared pedagogical framework, enabling a structured comparison between community-driven and industry-driven design contexts. While both projects required students to engage in open-ended problem solving and iterative design, they differed in terms of stakeholder expectations, decision-making criteria, and technical emphasis.

The MCCD project emphasized public-sector decision-making, regulatory compliance, and community-oriented value creation. Students were required to communicate technical recommendations to non-technical stakeholders, including facilities personnel and board members. This context reinforced stakeholder awareness, ethical considerations, and the ability to translate engineering analyses into accessible and actionable recommendations. The need to incorporate building codes, permitting requirements, and public accountability further introduced constraints that are characteristic of community-based engineering practice.

In contrast, the Verdantas project reflected an industrial consulting environment focused on performance optimization, feasibility, and system integration. Students evaluated multiple waste-heat recovery technologies and conducted trade studies considering efficiency, safety, installation complexity, maintenance requirements, and return on investment (ROI). This context emphasized quantitative analysis, technical rigor, and the justification of engineering decisions using performance metrics and economic evaluation. Interaction with the industry partner required students to defend assumptions and engage in technical discussions aligned with professional engineering practice.

All participating students were mechanical engineering majors enrolled in ME-340. Although the teams were not multidisciplinary in terms of academic majors, students were assigned differentiated functional roles within each project (e.g., technical analysis, economic evaluation, regulatory research, and stakeholder communication). This structure enabled role specialization and collaboration across multiple dimensions of the design process. While future iterations may incorporate multidisciplinary teams, this pilot implementation maintained disciplinary consistency to align with course learning objectives. Despite the differences in context and emphasis, both projects resulted in comparable patterns of student performance. Students demonstrated the ability to address ill-defined problems, incorporate real-world constraints into engineering design, and engage effectively with external stakeholders. These outcomes were observed consistently across both project environments, suggesting that the underlying pedagogical framework—rather than the specific project context—played a primary role in supporting student learning. Overall, the findings indicate that community- and industry-partnered design challenges can provide complementary yet equally effective learning environments within a unified instructional structure. The framework appears adaptable across diverse engineering contexts while maintaining alignment with ABET student outcomes and supporting the development of professional and entrepreneurial competencies.

5. Assessment and Rubrics

Student learning and the development of an entrepreneurial mindset across the MCCD and Verdantas projects were assessed using a unified framework aligned with the staged activities outlined in Tables 1 and 2. Assessment was intentionally distributed throughout the semester to emphasize iterative design, stakeholder engagement, and professional communication, rather than relying solely on final deliverables. Formative assessment was conducted during early project phases, including problem framing, conceptual design, preliminary calculations, and interactions with external stakeholders. Instructor feedback focused on technical reasoning, clarity of assumptions, and responsiveness to constraints. In parallel, feedback from community and industry partners provided authentic, practice-based evaluation of feasibility, professionalism, and value creation. This dual-feedback structure allowed students to iteratively refine their work based on both academic and real-world expectations. Summative assessment consisted of conceptual design reports, final technical reports, and oral presentations. A common analytic rubric was applied across both projects to evaluate four criteria: (1) technical analysis and engineering rigor, (2) stakeholder awareness and contextual understanding, (3) value creation and feasibility, and (4) professional communication. These criteria were aligned with ABET Student Outcomes SO2 (Engineering Design), SO3 (Communication), and SO5 (Teamwork), as well as KEEN entrepreneurial mindset dimensions.

Each criterion was evaluated using a four-level scale: Exemplary, Proficient, Developing, and Beginning. The rubric was designed to capture increasing levels of sophistication in engineering reasoning, stakeholder integration, and communication quality, while enabling consistent evaluation across both project contexts. As an example, performance levels for Engineering Design (SO2) were defined as follows:

- **Exemplary:** Develops multiple well-justified design alternatives; integrates stakeholder constraints; performs quantitative trade studies; explicitly evaluates feasibility, risks, and limitations.
- **Proficient:** Develops at least two viable alternatives; incorporates major constraints; provides quantitative justification for the selected design.
- **Developing:** Presents a single solution with limited constraint analysis and partial quantitative support.
- **Beginning:** Presents a conceptual solution with minimal analysis or justification.

Similar performance descriptors were used for communication (SO3) and teamwork (SO5), emphasizing clarity of technical communication, audience awareness, collaboration effectiveness, and contribution to team outcomes. Table 3 summarizes the alignment between the two projects, ABET student outcomes, and KEEN entrepreneurial mindset dimensions. A total of 11 students participated in the study, with 6 students assigned to the MCCD project and 5 to the Verdantas project. Aggregate rubric distributions were calculated across both projects. For Engineering Design (SO2), 86% of students achieved ratings of Proficient or Exemplary. For Teamwork (SO5), 93% achieved Proficient or above. For Communication (SO3), 79% achieved Proficient or above. Mean rubric scores (on a 4-point scale) were 3.21 for SO2, 3.36 for SO5, and 3.07 for SO3. These results indicate that the majority of students met or exceeded expected performance levels across key learning outcomes, particularly in teamwork and design-related competencies. Communication outcomes showed slightly greater variability, which is consistent with the increased complexity of addressing multiple stakeholder audiences, including non-technical participants. Because no baseline or control group was used, results are interpreted descriptively rather than comparatively. The findings, therefore, reflect observed levels of student performance within the implemented framework rather than measured improvement relative to prior course offerings.

Table 3. Mapping of MCCD and Verdantas Projects to ABET Student Outcomes and KEEN Entrepreneurial Mindset (3Cs)

Project	ABET SO2 (Engineering Design)	ABET SO5 (Teamwork & Communication)	KEEN 3Cs
MCCD – Energy Resilience	Defined an open-ended community problem; incorporated public-sector constraints, codes, and economic considerations into a solar–battery system design	Coordinated team roles; communicated technical recommendations to non-technical stakeholders (staff, board members)	Curiosity: understanding community energy needs Creating Value: resilience and reliability for public facilities
Verdantas – Waste Heat Recovery	Evaluated multiple design alternatives; performed trade studies considering efficiency, safety, and ROI for industrial heat recovery systems	Collaborated in functionally diverse teams; engaged in professional technical dialogue with industry mentors	Curiosity: exploring multiple recovery technologies Making Connections: linking thermodynamics, economics, and safety Creating Value: efficiency gains and cost savings

6. Conclusion

This paper presented a community- and industry-driven innovation challenge framework implemented in a required undergraduate mechanical engineering design course (ME-340: Design Methodology) through two complementary case studies: a community-based energy resilience project with the Monroe County Conservation District and an industry-partnered waste heat recovery project with Verdantas Engineering. Grounded in Project-Based Learning (PjBL) and entrepreneurial mindset principles, the framework was designed to expose students to authentic, open-ended engineering problems involving real stakeholders, constraints, and accountability.

Despite differences in context, scale, and technical focus, both projects produced comparable patterns of student performance. Students demonstrated the ability to define ill-structured problems, evaluate alternative solutions, incorporate stakeholder input, and communicate technical recommendations in professional settings. These outcomes were supported by rubric-based assessment results, which indicated high levels of attainment in ABET Student Outcomes SO2 (Engineering Design), SO3 (Communication), and SO5 (Teamwork). The use of a common analytic rubric enabled consistent evaluation across both project contexts while maintaining alignment with KEEN entrepreneurial mindset dimensions.

The results suggest that community- and industry-partnered design challenges can be effectively integrated into core undergraduate engineering courses without sacrificing technical rigor. By maintaining consistent learning objectives and assessment criteria while varying project context, the proposed framework provides a scalable and adaptable model for enhancing experiential learning, professional readiness, and entrepreneurial mindset development.

This instructional approach will be continued and further refined in the Fall 2026 offering of ME-340, building on lessons learned from the pilot implementation. Planned enhancements include expanded stakeholder engagement, improved assessment instruments, and the potential incorporation of multidisciplinary collaboration to further strengthen the framework's educational impact.

As a pilot study without a baseline or control group, the findings are interpreted descriptively rather than comparatively. Future work will focus on longitudinal tracking of student outcomes, incorporation of comparative data across course offerings, and broader implementation across additional courses and institutional contexts.

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