Missing Links of the Industry Partnership Capstone for Engineering Students

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Abstract

Industry-partnered capstone projects are designed to help engineering students integrate technical knowledge with real-world practice. However, these collaborations often fall short of expectations due to misalignments between academic and industrial goals. This study investigates the missing links that constrain the effectiveness of industry partnership capstone projects. Five critical issues were identified: unclear project objectives, inconsistent communication, insufficient professional skills of students, restricted authentic industry engagement, and value proposition. The findings indicate that divergent priorities and timelines between universities and corporations frequently undermine both learning and partnership outcomes. To address these challenges, the study proposes a framework emphasizing early goal alignment, structured communication and mentoring, continuous feedback, and sustained engagement. Strengthening these missing links can enhance student learning, improve project outcomes, and foster more enduring university-industry collaborations in engineering education.

Keywords: Industry partnership, capstone, experiential learning, academic-industry collaboration, project-based learning, engineering education, strategic alignment

1. Introduction

Traditionally, engineering higher education institutions have introduced experiential learning curricula through senior design capstone projects in partnership with local corporations and industrial alumni networks [1,2,19,20]. Industries value higher education institutions as ideal partners for outsourcing research and development activities and enhancing competitiveness through the exchange of knowledge and technology. In turn, industry partnerships provide universities with a value-added source of funding to support research activities. However, traditional approaches often lack sufficient depth to adequately prepare students for complex, real-world applications.

Active learning surpasses traditional passive learning by encouraging students to engage in activities that foster critical thinking and problem-solving skills to address contemporary business challenges [3,12,16,17]. A common challenge lies in how to integrate interactive, collaborative, multidisciplinary, and authentic engineering practice into corporate partnerships [4,13,15]. The literature reveals similar gaps in supplier partnerships and collaborations worldwide, including aerospace industries in India, building materials sectors in Africa, industry stakeholders in Lavita, the construction industry in Vietnam, and industries in the Netherlands [6–11]. Many researchers argue that reforms in higher education consistently lag evolving industry needs [18]. Furthermore, engineering graduates often lack effective communication skills, and limited industrial trust continues to challenge alignment between academic programs and workplace expectations [5,17,19]. Fostering alumni engagement may serve as a critical bridge to enrich such collaborations. The purpose of this paper is to investigate the missing links that constrain the effectiveness of common industry-partnered capstone projects for engineering students. Five critical areas are examined in the following sections:

A. Misalignment of goals and expectations

B. Inconsistent communication and mentorship

C. Insufficient professional skills of students

D. Restricted authentic industry engagement

E. Impact on value proposition

This study is based on lessons learned from the Industrial Engineering – Professional Master's Program (PMP) at Purdue University over the past 5 years. A total of 57 PMP semester-long capstone projects were executed by 72 graduate students in collaboration with 16 major corporations, including American Airlines, Apple, Canon Medical, Caterpillar, CNH Industrial, Continental Tire, Cummins, Dana, Eaton, GE Aerospace, Tesla, Thermo Fisher Scientific, and others. Due to the complexity of certain capstone projects, substantial industry grants were received from various sponsors to support travel expenses, deliverables, and PMP outstanding student awards.

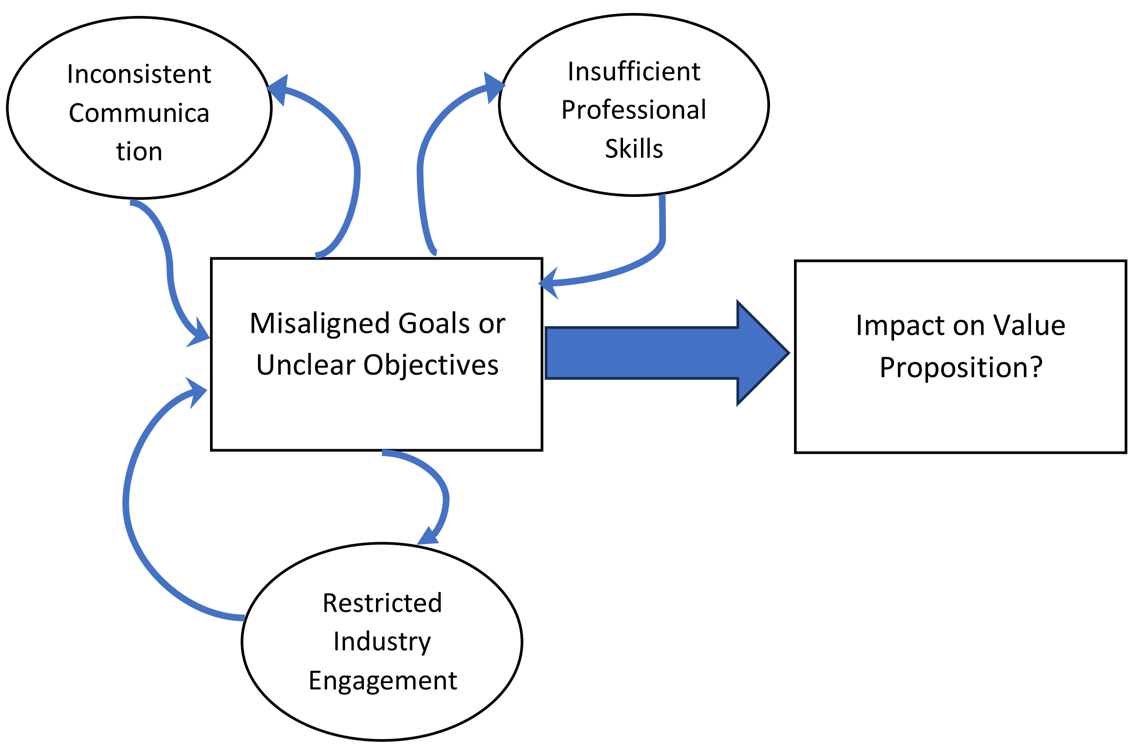

Figure 1: System Thinking Model to constrain Effectiveness of Industry Capstone Projects

This study employs a structured survey instrument consisting of five purposefully designed questions to assess experiential learning effectiveness and capture stakeholder perceptions. The survey targets engineering students and faculty advisors/mentors across eight Carnegie-designated R1 research institutions located in the West Coast, Midwest, Southern, and East Coast regions of the United States. The subsequent sections examine each survey question in detail.

2. Misalignment of Goals and Expectations

The complexity of capstone projects ranges from academic exercises (e.g., linear programming for optimizing an inventory planning problem) to projects with unrealistic industry expectations (e.g., setting up a robotic integration system). This variation largely depends on how well the project scope and expected deliverables are reviewed and defined at the beginning of the semester. In addition, industry executive sponsors may choose to structure projects into multiple phases (e.g., 4, 8, or 12 months).

1st Survey Question: Based on your experience, how would you characterize Industry Capstone Projects in terms of goal and expectation alignment?

A) **Misaligned** – Unrealistic expectations, ambitious objectives, or scope can be changed.
B) **Academically Oriented** – Clearly defined scope, but primarily focused on academic learning outcomes.
C) **Time-Constrained** – Clearly defined practical objectives, but insufficient time for implementation within one semester.
D) **Well-Aligned** – Clearly defined scope and deliverables with practical, on-site impact over a 9–12 month duration.

Such misalignment is commonly observed in undergraduate senior design capstone projects. Students frequently struggle to connect technical deliverables with broader organizational value and business impact. Limited prior industry exposure further constrains their ability to identify systemic gaps and formulate implementable engineering solutions, particularly when sponsors provide ambiguously defined problem statements or incomplete project framing. In cases where faculty advisors maintain limited interaction with industry sponsors, student teams lack the authority and structural support necessary to recalibrate project scope when complexity exceeds the standard 10–13 working week timeline. Conversely, insufficient project depth may also result in perceived under-challenge, raising concerns about academic rigor and experiential value.

3. Inconsistent Communication and Mentorship

Communication is essential to the success of any academic - industry project. Depending on each team's agreed-upon structure with the sponsor, the frequency of meetings with the industry team may vary from twice a month to twice a week. However, many academic advisors and faculty members have acknowledged that they rarely attend weekly meetings with industry sponsors or visit sponsor facilities alongside student teams.

2^{nd} Survey Question: Based on your experience, how would you characterize communication and mentorship practices in Industry Capstone Projects?

A) **Fragmented Communication** – Irregular communication among students, faculty advisors, and industry sponsors; reliance primarily on email; limited faculty participation in meetings; delayed feedback affecting project progress.

B) **Partially Coordinated** – Students meet weekly with the industry sponsor and separately with the faculty advisor; limited integration among all three parties.

C) **Periodic Joint Engagement** – Faculty advisor, industry sponsor, and students meet jointly once per month for progress updates.

D) **Highly Integrated Collaboration** – Two or more weekly onsite or virtual meetings involving students, industry sponsors, and faculty advisors; consistent real-time communication (e.g., Teams, WhatsApp); active faculty engagement in understanding business challenges and coaching both students and sponsors.

Conversations with over 100 faculty members from multiple R1 institutions over the past five years suggest that capstone advising commonly follows an academic mentoring model, wherein faculty meet weekly with student teams in a structure resembling graduate research supervision. Students, however, are generally responsible for managing interactions with industry sponsors independently, whether virtually or in person.

This structural separation creates a temporal and cultural misalignment between academic and industry expectations. In industry settings, responsiveness and urgency are integral to effective collaboration and decision-making. Yet, it is not uncommon for students to respond to sponsor communications after delays of two to four days, despite business contexts in which decisions may be required within hours.

Furthermore, many students adopt a reactive work pattern, postponing substantive progress until immediately before weekly meetings. Such behavior often reveals gaps in data or information too late to recover within the same cycle, thereby delaying progress. When this pattern recurs one to three times within a 16-week semester, the cumulative time loss becomes substantial, directly undermining project deliverables and experiential learning objectives. A simple temporal calculation underscores the risk: in a 13 working-week engagement, the loss of several productive weeks can fundamentally compromise project success.

4. Insufficient Professional Skills of Students

Engineering students may lack readiness in project management and people-engagement skills. Engineering curricula often do not adequately cover topics such as team building, time management, conflict resolution, or change management. Furthermore, training in digital operational excellence, Design for X, and tools such as Power BI is offered only to a limited extent. In academia, it is commonly assumed that students can gain substantial experiential learning through summer internships and co-op experiences. However, the degree of difficulty and responsibility associated with internships is not comparable to that of full-time engineering roles. For most major corporations, internships and co-op programs primarily serve as mechanisms to evaluate whether a student is a suitable candidate for full-time employment upon graduation. Perspectives shared by senior managers and executives suggest that summer internships are primarily structured as talent development pipelines rather than performance-driven business initiatives. Consequently, organizations generally do not anticipate significant or measurable business impact from these limited-duration assignments.

3rd Survey Question: Based on your experience, how would you assess students' professional readiness in Industry Capstone Projects?

A) **Insufficient Foundational Skills** – Limited readiness in project and time management, client engagement, conflict resolution, and operational excellence (OpEx) principles.

B) **Limited Industry Tools Exposure** – Minimal training in project management and limited exposure to industry standards and tools (e.g., APQP, PFEP, Lean Six Sigma, DFX, SAP, Power BI, FlexSim, Digital Twin).

C) **Restricted Executive-Level Experience** – Some industry exposure through internships or co-ops, but limited experience in business negotiation and executive-level storytelling or presentation.

D) **Strong Professional Integration** – Intensive digital operational excellence training combined with regular on-site or virtual engagement with senior executives under structured professional mentorship.

The misalignment between academic preparation and industry expectations remains a systemic concern for engineering education. Evidence of this gap can be inferred from the substantial annual investments corporations make in structured Leadership Development Programs (LDPs). Engineering graduates are commonly recruited into rotational programs spanning 18–36 months, with assignments across Product Development, Manufacturing Operations, Supply Chain, and Technical Applications functions. These programs are intentionally designed to cultivate cross-functional awareness, operational discipline, and leadership capacity; competencies not consistently developed within traditional undergraduate curricula.

The scale and duration of these initiatives signal that corporations perceive undergraduate engineering education as insufficient for immediate high-impact contribution. Consequently, there is an urgent need to re-examine pedagogical models and embed experiential, interdisciplinary, and industry-integrated learning more deeply within core technical coursework. Partnerships between higher education institutions and industry sponsors, through grants, co-developed modules, and applied learning ecosystems, may serve as mechanisms to narrow this readiness gap. Programs such as the MIT NEET Program at Massachusetts Institute of Technology demonstrate how project-centric, interdisciplinary curricula can systematically integrate professional skill development with technical mastery.

Regular dialogue with corporate executives further reinforces concerns that many graduates lack the technical agility, digital fluency, and execution intensity required in contemporary engineering environments. In certain cases, curricula have not evolved at a pace commensurate with enterprise-scale digital transformation initiatives underway in major global corporations.

5. Restricted Authentic Industry Engagement

For most engineering capstone teams, budgets for regular travel to sponsor facilities are limited, often due to geographic proximity constraints. In addition, some major corporations have policies that restrict the sharing of internal data and information needed to support capstone projects, resulting in the use of sanitized or minimal datasets. In many cases, the primary project sponsor engages with the student team only during the project kickoff and final presentation. Most ongoing interactions occur between students and assigned engineers or project engineers, rather than managerial-level stakeholders.

4th Survey Question: Based on your experience, how would you characterize the level of authentic industry engagement in Industry Capstone Projects?

A) **Minimal On-Site Exposure** – No hands-on facility visits during the semester; engagement limited to weekly or biweekly virtual meetings with industry sponsors.

B) **Declining Industry Participation** – Active involvement at project kickoff, followed by reduced engagement; infrequent meetings; projects potentially simplified relative to real industry complexity.

C) **Restricted Data Access** – Regular meetings maintained, but limited access to production data due to sanitization or proprietary constraints.

D) **Full Industry Integration** – Comprehensive facility access, availability of operational data under nondisclosure agreements (NDAs), and regular working sessions with plant or senior managers.

Limited funding for capstone projects constrains the extent to which student teams can conduct on-site visits to industry-sponsored facilities, thereby reducing opportunities to develop contextual understanding of products, processes, and operational constraints. Restricted access to production and supply chain data further diminishes the potential for meaningful business impact. Over the past five years, several major corporations, including Tesla, Apple, and GE Aerospace, have enforced stringent policies limiting the sharing of proprietary operational data with student capstone teams, even under formal non-disclosure agreements. While such policies are understandable from a risk management perspective, constrained data access inevitably limits analytical rigor and practical relevance. In computational and simulation contexts, this limitation reflects the well-known principle of “garbage in, garbage out,” whereby insufficient or low-quality inputs restrict the validity of outcomes.

In contrast, corporations such as Caterpillar, Eaton, and American Airlines have adopted a more integrated partnership model by embedding students from the PMP as extended team members. In these collaborations, students are granted structured access to relevant internal datasets, conduct frequent site visits, evaluate multiple operational scenarios, and develop predictive and prescriptive analytics solutions. Functioning effectively as an external digital Operational Excellence (OpEx) consulting team, students contribute to measurable process improvements while simultaneously gaining authentic enterprise experience.

Such reciprocal partnerships often yield mutual benefits. Executive leaders demonstrate stronger commitment by allocating cross-functional resources from Engineering, Operational Excellence, Quality, and Supply Chain functions to support sponsored projects. These deeper collaborations not only enhance the likelihood of tangible operational impact but also create pathways for talent identification and subsequent employment opportunities.

6. Impact on Value Proposition

Conventionally, the assessment of engineering capstone projects focuses on elements such as team reports (15–20 pages), PowerPoint presentations, project posters, and industry sponsor feedback. In most cases, measurable industry outcomes or solution implementation are not the primary evaluation criteria due to limitations in access to internal data and time constraint. Nevertheless, if the initial project scope were better aligned with the industry's strategic roadmap and included clearly defined, measurable targets (e.g., reducing inventory by 20-30% or improving productivity by 20-40%), the overall capstone experience could provide greater benefits to both industry and academia.

5th Survey Question: Based on your experience, how effectively did the Capstone assessment reflect industry value proposition?

A) **Academically Driven Assessment** – Evaluation primarily based on reports and presentations rather than measurable industry outcomes (a nice engineering tryout/practice).

B) **Strategic Misalignment** – Project scope not aligned with the sponsor's strategic roadmap or priority initiatives, limited direct business impact (no urgency in 12 months).

C) **Unclear Implementation Path** – Project outcomes generated but sponsors uncertain about implementation feasibility or measurable value realization (no deployment plan).

D) **Strategically Aligned Value Creation** – Assessment aligned with corporate strategy and priorities; final deliverables demonstrate measurable business impact and clear value proposition.

Over the past five years, several senior executives, particularly new industry sponsors, have questioned the comparatively substantial grant levels requested to support each PMP project relative to traditional senior design capstone models in other departments (e.g., business schools) or peer institutions. As reported in prior studies [22], a typical undergraduate senior design capstone project receives industry sponsorship ranging from $0 to $7,000 per semester. In contrast, individual projects within the PMP may require grants ranging from $65,000 to $130,000 over a 9-12 month engagement period, inclusive of travel expenses and applicable indirect costs.

This financial differential reflects a fundamentally different value proposition. Senior global executives evaluate such investments through a business lens, emphasizing measurable returns, strategic alignment, and long-term organizational benefit. Sponsorship decisions are therefore guided not merely by educational goodwill, but by anticipated operational improvements and tangible economic gains.

In practice, senior executive leaders, many of whom are distinguished alumni, assess sustained partnership with the PMP along four primary dimensions:

1. **Value proposition and quantifiable business impact**, often expressed in direct or indirect financial return.
2. **Strategic alignment** with corporate priorities, digital transformation initiatives, or operational excellence objectives.
3. **Talent pipeline development**, enabling proactive recruitment for internships and full-time positions while reducing hiring and onboarding costs through early identification of high-potential candidates.
4. **Long-term academic–industry partnership**, designed to jointly address evolving technological and operational challenges.

Viewed through this framework, the higher sponsorship level reflects a shift from a transactional capstone model toward a strategic partnership model, wherein student teams function as embedded contributors capable of delivering enterprise-level value rather than purely academic outputs.

7. System Thinking to Improve Effectiveness of Industry Capstone Projects

The gap between academia and industry sponsors can be narrowed by introducing the following systems-thinking model to enhance the effectiveness of industry-partnered capstone projects. This model has been successfully implemented at the Edwardson School of Industrial Engineering in Purdue University over the past five years.

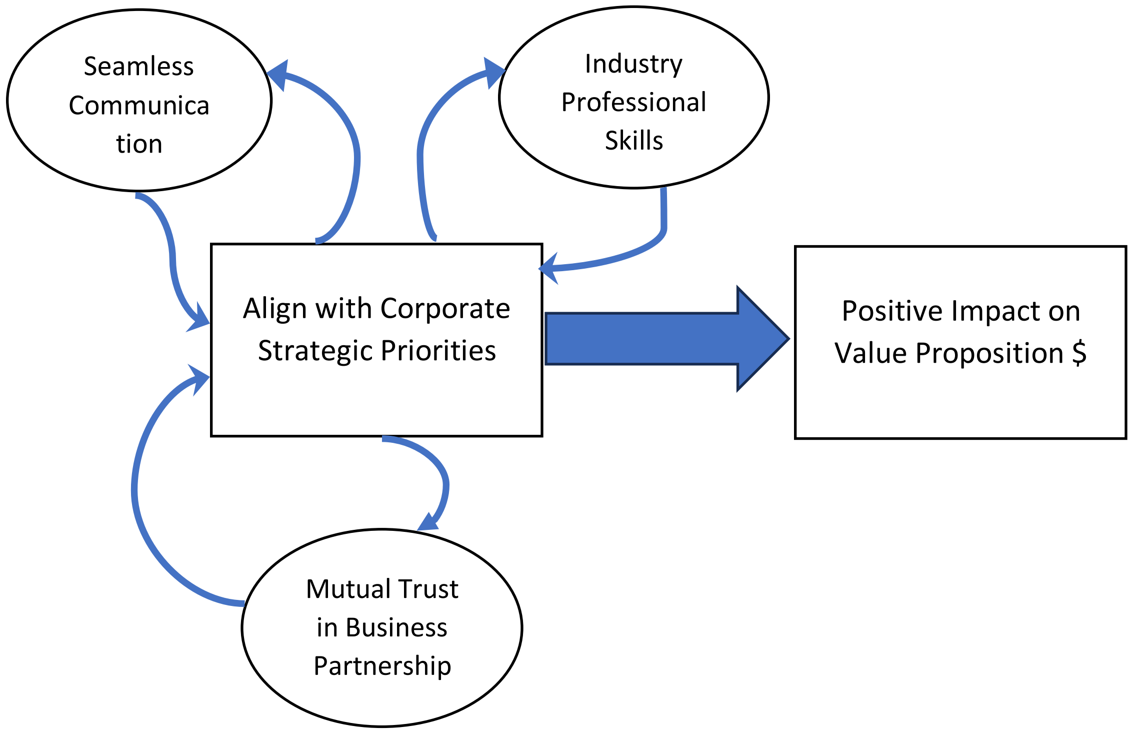

Figure 2: System Thinking Model to improve Effectiveness of Industry Capstone Projects

Over the five years, a total of 57 semester-long PMP capstone projects have been executed in collaboration with 16 major corporations. These engagements have resulted in measurable operational improvements and documented cost savings for participating industry sponsors.

To further evaluate the experiential learning model and systematically compare outcomes across institutions, the authors developed a structured survey instrument consisting of five targeted questions. The survey is designed to assess experiential quality and quantify feedback from engineering students and faculty advisors at eight R1 research institutions representing the West Coast, Midwest, Southern, and East Coast regions of the United States.

The initial survey distribution occurred in December 2025. However, because many participating institutions offer Senior or Master's Design Capstone courses exclusively during the Spring semester, response rates were limited. The survey will therefore be redistributed in April 2026 to align with course delivery cycles.

Upon completion of data collection, the authors intend to employ empirical analysis and a structured analytic framework to identify cross-institutional patterns, compare experiential models, and generate evidence-based insights among U.S. R1 institutions. The findings are expected to inform future scholarly dissemination and contribute to the broader discourse on industry-integrated engineering education.

8. Conclusions

Industry-partnered capstone projects are intended to integrate technical knowledge with authentic real-world practice, thereby enhancing both student learning and professional readiness. However, these collaborations frequently fall short of their intended objectives due to structural misalignments between academic priorities and industrial expectations. This study examines the "missing links" that constrain the effectiveness of industry-partnered capstone models by analyzing five critical dimensions that significantly influence overall project success.

The investigation identifies several systemic factors that contribute to persistent goal misalignment across institutions. Inconsistent communication structures, limited faculty engagement with industry sponsors, and insufficient mechanisms for iterative feedback collectively undermine project performance. In addition, evidence suggests that engineering students may not consistently receive adequate professional preparation to operate effectively within digitally driven, data-intensive business environments.

Although numerous corporate sponsorships exist, many remain transactional in nature rather than strategically integrated. Such engagements often function as short-term or annual arrangements, emphasizing sponsorship presence rather than long-term collaboration. Consequently, these relationships may evolve into trusted but limited partnerships rather than deeply embedded academic - industry ecosystems. In some cases, partnerships dissolve following initial engagement, limiting sustained impact.

When industry partners commit to full and strategic engagement, including data access, executive sponsorship, and cross-functional participation, a mutually beneficial outcome becomes achievable. Such collaborations can generate measurable financial and operational value for industry stakeholders while simultaneously strengthening academic programs and enhancing student experiential learning. Addressing these structural gaps can therefore improve project outcomes, elevate student competency development, and foster more durable and strategically aligned university - industry partnerships in engineering education.

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