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MAKER: Impact of Industry-Sponsored Interdisciplinary Capstones on Higher-Order Competencies: A PEI-Based Comparative Study

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Abstract

This paper evaluates the impact of industry-sponsored interdisciplinary capstone projects on the development of higher-order engineering competencies in an Engineering Technology (ET) program at Drexel University. The study is based on a year-long, industry-sponsored senior design project conducted in collaboration with SouthCo, Inc., which addressed an ergonomic and safety challenge in manual material handling. A multidisciplinary team of Mechanical, Manufacturing, and Electrical Engineering Technology students designed, analyzed, and fabricated an ergonomic bin-handling cart capable of safely lifting, transporting, and lowering stacked injection-molded component bins.

Following an industry-informed engineering design process, the team performed customer requirement analysis, conceptual design, CAD modeling, finite element analysis, prototyping, and iterative testing. The final design met ANSI B11 and OSHA 1910 standards, with deliverables including two functional hydraulic-lift carts, detailed CAD assemblies, and comprehensive technical documentation.

To assess educational outcomes, student performance was evaluated using Performance Evaluation Indicators (PEIs) aligned with ABET ETAC Student Outcomes. Longitudinal analysis across the three-quarter capstone sequence showed consistent improvement, particularly in higher-order competencies such as design justification, system integration, and professional communication. A comparative analysis of Spring 2023 and Spring 2024 cohorts, including 10 teams with 5 industry-sponsored projects, indicates that industry-sponsored teams achieved stronger performance in these areas compared to faculty-developed projects, while differences in foundational technical knowledge remained minimal.

These findings suggest that industry-sponsored capstone experiences enhance applied engineering competencies by introducing real-world constraints, stakeholder interaction, and accountability. The results support the role of project-based learning, combined with authentic industry collaboration, in strengthening ABET-aligned outcomes and better preparing Engineering Technology graduates for modern manufacturing environments. The paper also discusses instructional structure, assessment methods, and implications for continuous program improvement.

1. Introduction

Modern manufacturing increasingly demands ergonomic efficiency, safety, and sustainability. Engineering Technology (ET) programs are uniquely suited to meet these needs through project-based learning (PBL), which bridges theoretical instruction and hands-on industrial practice. This paper describes a year-long, interdisciplinary capstone at Drexel University sponsored by SouthCo, Inc Manufacturing—a global producer of engineered components—focused on developing an ergonomic bin-handling cart for safer material transport on the factory floor.

Four ET students representing mechanical, manufacturing, and electrical disciplines applied an engineering-design-process framework guided by both faculty and industry mentors. The project not only produced a functioning device but also illustrated how industry collaboration enhances experiential learning, professional responsibility, and alignment with ABET Student Outcomes.

2. Senior Design Capstone Course Sequence in Engineering Technology

The senior design experience at Drexel University serves as the culminating capstone sequence within the Engineering Technology (ET) curriculum. Structured as a three-quarter course sequence—MET 421 (Senior Design Project I), MET 422 (Senior Design Project II), and MET 423 (Senior Design Project III)—the capstone spans an entire academic year and is a required component of the ET core curriculum. This extended format provides students with a comprehensive, iterative design experience that closely mirrors professional engineering practice.

3. Educational Objectives and Pedagogical Framework and Research Question

The senior design sequence is structured to integrate and apply knowledge acquired throughout the Engineering Technology (ET) curriculum to solve real-world, multidisciplinary engineering problems. The course emphasizes the development of both technical and professional competencies, including system analysis and design, technical writing, oral communication, teamwork, and project management. Project-Based Learning (PBL) serves as the foundation of the sequence, guiding students through formal stages of design, implementation, testing, and validation.

All senior design projects are required to incorporate relevant engineering codes and industry standards while addressing considerations of public health, safety, ethics, and sustainability. Students evaluate a broad range of constraints, including economic feasibility, manufacturability, environmental impact, and societal implications at both local and global levels. Through this structured approach, the capstone sequence directly supports ABET ETAC Student Outcomes and provides a robust framework for program assessment and continuous improvement.

As a representative example, this paper examines an industry-sponsored capstone project focused on the design and fabrication of an ergonomic bin-handling cart for a manufacturing partner. The project required students to address real operational constraints—including safety standards, budget limitations, manufacturability, and usability—while delivering a fully functional prototype validated through analysis and testing. This project serves as a case study to illustrate how industry collaboration enhances both technical depth and professional skill development within the capstone experience.

Within this context, the present study also investigates the following **research question:**

How does participation in an industry-sponsored, interdisciplinary capstone project influence student development of higher-order engineering competencies—such as analysis integration, design justification, and professional communication—compared to traditional capstone experiences?

3.1 Project Selection and Design Scope

Senior design projects are intentionally open-ended and originate from diverse sources, including student cooperative work experiences, faculty research initiatives, instructional laboratory needs, and industry-sponsored problems. Students may also propose projects based on prior employment or organizational affiliations. Topics are broadly defined, allowing students to shape the scope and direction of their work. Project teams typically consist of two to four students, encouraging interdisciplinary collaboration across ET concentrations.

During the initial phase of the sequence, students conduct background research to identify needs and opportunities, leading to a clearly articulated problem statement and set of design specifications. Structured design tools such as Quality Function Deployment (QFD), concept generation methods, and decision matrices are used to evaluate alternative solutions. Life-cycle analysis is incorporated to assess proposed concepts under economic, environmental, and sustainability constraints. Design for X principles—including Design for Manufacturing, Assembly, and Environment—are explicitly addressed alongside human factors and ergonomic considerations.

3.2 Instruction, Mentorship, and Learning Activities

Instruction is coordinated by a senior design course coordinator and supported by faculty teaching the capstone courses. Each project team is assigned to at least one faculty advisor, and industry-sponsored projects include one or more industry mentors. Throughout the three quarters, students participate in weekly seminar-style meetings that combine project organization with targeted instructional modules.

Instructional topics include literature review techniques, engineering standards and codes, patent search and intellectual property considerations, product design and liability, technology commercialization, project management, economic analysis, and life-cycle assessment. Sustainability and societal impact are emphasized throughout the sequence. Guest lectures are frequently delivered by faculty, industry practitioners, and subject-matter experts, including legal professionals addressing product liability and regulatory compliance.

3.3 Assessment Structure and Milestones

Assessment in the senior design sequence is continuous, structured, and multifaceted. Students participate in workshops, roundtable discussions, and formal presentations of project progress. Weekly team meetings with faculty and industry mentors are documented through meeting minutes, and each team submits a weekly status report outlining completed tasks, upcoming goals, and planned actions. This structure promotes accountability and supports steady project progression.

Each quarter culminates in a major assessment milestone consisting of an oral presentation and a written technical report evaluated by project advisors and additional faculty reviewers. Performance is assessed using ten Performance Evaluation Indicators

(PEIs), scored on a Likert scale from 0 to 5 for both oral and written components. The PEIs are aligned with course goals and ABET ETAC Student Outcomes.

The assessment focus evolves across the three terms. The Fall term emphasizes research, literature review, problem definition, and project planning, culminating in formal project proposals. The Winter term focuses on technical analysis, concept refinement, and preliminary validation. The Spring term emphasizes final implementation, testing, validation, and comprehensive documentation of results and conclusions. All three courses require full written reports, with the Fall and Spring terms designated as Writing Intensive.

3.4 Culmination and Integration

The capstone sequence concludes with final oral presentations delivered to ET faculty, industry mentors, peers, and external reviewers. These presentations provide a comprehensive overview of technical outcomes, standards compliance, and societal and ethical considerations. Following the final presentations, ET faculty review completed projects and selected one to represent the program in the College of Engineering Senior Design Competition.

Overall, the three-quarter senior design capstone sequence provides a high-impact educational experience that integrates technical expertise, professional skills, and ethical responsibility. By engaging students in authentic, industry-relevant design challenges and emphasizing continuous assessment and reflection, the sequence effectively prepares Engineering Technology graduates for professional practice and lifelong learning.

4 Ergonomic Cart Design Project Background and Motivation

4.1 Ergonomic and Safety Challenges

Manual material handling remains a major cause of workplace injury. At SouthCo, Inc Manufacturing, operators routinely lifted stacks of injection-molded bins from near-floor level, increasing strain and fatigue. The project's goal was to reduce risk by designing a hydraulically actuated cart that could elevate, stabilize, and transport bin stacks up to 230 lb. within 36-inch aisles while satisfying ANSI B11 and OSHA 1910 standards.

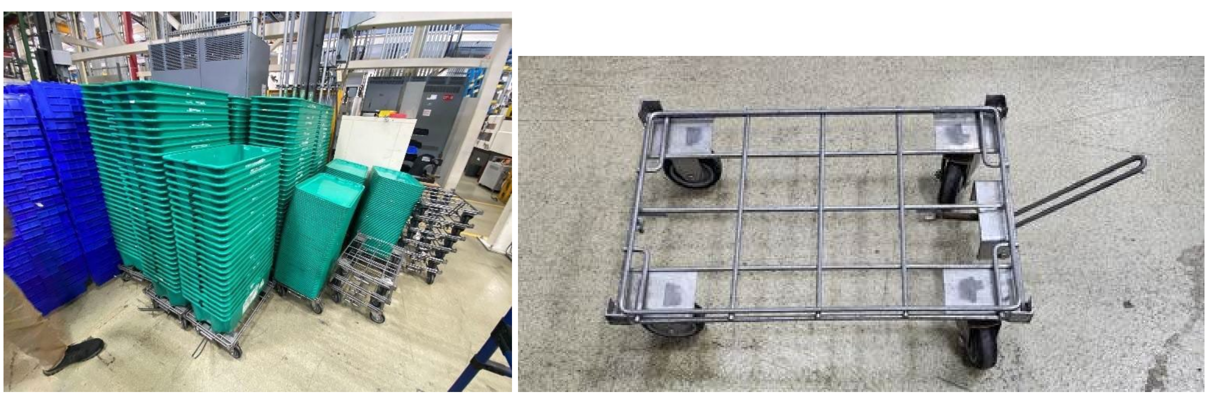


Figure 1. Green Tote Bin Storage at SouthCo, Inc Facility (left)

Current Wheeled Dollies Used to Transport Stacks of Green Tote Bins (Right)

4.2 Industry Collaboration as a Learning Catalyst

Weekly design reviews with SouthCo, Inc Manufacturing engineers exposed students to authentic industrial constraints—budget limits, ergonomic requirements, and documentation procedures—cultivating professional communication and accountability consistent with ABET Criterion 3.

4.3 Project Description: Scope and Objectives

The team aimed to design and fabricate a functional cart that would

- Lift and lower stacked bins with minimal operator effort;
- Secure loads against tipping or slippage;
- Maneuver safely in 36-inch aisles;
- Meet ANSI B11 and OSHA 1910 compliance; and
- Stay within a $1,500 budget.

Deliverables included two functional hydraulic-lift carts, CAD models, FEA analyses, ergonomic evaluations, and technical documentation.

4.4 Team Composition and Roles

Two Mechanical ET students handled structural design and analysis; one Manufacturing ET student led fabrication and cost control; one Electrical ET student developed safety interlock concepts. Faculty and industry mentors jointly supervised three design milestones aligned with the university's capstone sequence.

4.5 Engineering Design Process: Methodology

Customer needs were translated into engineering requirements via a House of Quality. Four concepts were generated and evaluated with a weighted-decision matrix; a hybrid design offering optimal manufacturability and ergonomic performance was selected.

Ergonomic Bin Handling Cart		Engineering Characteristics													
Improvement Direction		↓	↑	↓	↓	↓	↑	↑	↓	↑	↑	↓	↓	↓	↓
Units		lbf	in	in	in	kWh	in	in	lbf	Friction Coefficient	Deflection	in	$	in/s	lb
Customer Requirements	IWF	Actuation Force	Bin Alignment Clearance	Cart Width	Center of Gravity	Energy Usage	Ground Clearance	Height	Push/Pull Force	Slippage	Stiffness	Turn Radius	Unit Cost	Vertical Speed	Weight
Carry Bins and Lids	10				7		8		6	10	6	4			
Durable	6			4		2			2	2	9		1		3
Easily Visible	8					1		10					3		
Easy to Maintain	8		2	3	2	3		3		4	6			1	5
Easy to Operate	7	10	8	7	2			5	1			10		3	6
Easy to Understand	7								1						
Ergonomically Sound	10	10	1	4	4		6	2	8		1	4			9
Inexpensive	3	2	1	3	4	10	2	3	5		4	1	10	1	4
Lift Bins	9	2				3	5			3	1		1	9	1
Lift Lids	3	2				3	5			3	1		1	9	2
Lightweight	4		1	3	5	3	2	4	4						10
Mobile	10		5	9	9				10			10	1		7
Place Bins and Lids	7	2				3	5			2	1		1	9	
Quiet Operation	1	2		2				1					1		1
Safe to Operate	10	9		6	6	4	3	4	8	5	1	2	8	8	3
Simplistic Design	6	4				7	4			2		1	7	6	2
Space Conscientious	5		10	8				1				8			
Stable	6	4	3	10	10		9	8	6	9	6	4		3	5
Raw Score:		354	207	410	382	225	357	278	413	310	249	343	212	337	400
Relative Weight:		7.91%	4.62%	9.16%	8.53%	5.03%	7.97%	6.21%	9.22%	6.92%	5.56%	7.66%	4.74%	7.53%	8.93%
Rank Order:		6	14	2	4	12	5	10	1	9	11	8	13	7	3

Figure 2. House of Quality (partial)

4.6 Design Specifications

The cart design parameters were established based on customer requirements, engineering constraints, and applicable safety standards. The cart width was constrained to a maximum of 36 inches to comply with standard factory aisle dimensions, with a minimum width of 14.75 inches to accommodate bin geometry. Vertical design limits were governed by OSHA guidelines, setting a maximum stack height of 60 inches while maintaining operability from an unloaded condition. The cart was designed to lift variable loads ranging from zero to a full stack of 35 bins or 100 lids, ensuring flexibility in daily operations. Additional specifications included controlled approach clearance to improve alignment tolerance, adequate ground clearance to prevent floor interference, and ergonomic actuation force limits for both hand and foot operation in accordance with CCOHS guidelines. Structural design targets included a factor of safety between 1.5 and 2.5 for a maximum payload of 300 pounds. Finally, economic constraints required the cart design to remain within a per-unit budget of $1,000 and an overall project budget of $3,500, ensuring cost-effective implementation.

Table 1. Design Specifications

Parameter	Minimum	Maximum	Units	ID	Rationale
Cart Width	14.75	36	in	↓	Bin Width and OSHA Isle Widths
Stack Height	0	60	in	=	OSHA Standard
Cart Height	36	60	in	=	OSHA Standard
Bin Stack	0	35	Bins	=	OSHA Standard
Lid Stack	0	100	Lids	=	OSHA Standard
Approach Clearance	1	4	in	↑	Improves Operator Ease of Use
Ground Clearance	2	4	in	↑	Prevents Lifted Stack from Dragging
Actuation Force (Hand)	0	33	lbf	↓	CCOHS Ergonomic Guidelines
Actuation Force (Foot)	0	64	lbf	↓	CCOHS Ergonomic Guidelines
Factor of Safety	1.5	2.5	N/A	=	*Machine Elements in Mechanical Design* - Mott
Quantity of Carts	2	3	Carts	↓	Southco Deliverable
Cost Per Cart	0	1000	USD	↓	Southco Deliverable
Overall Budget	0	3500	USD	↓	Southco Deliverable

4.7 Design Alternatives

Several design alternatives were evaluated during both the conceptual and detailed design phases of the project. One option considered was the use of hydraulic pistons for stack clamping in place of the selected mechanical horizontal clamp; however, this approach was eliminated due to its significant impact on system cost. The team also evaluated the integration of electronic components, including motorized lifting or clamping mechanisms and motion sensors to enhance user safety and ergonomics. While such features could simplify operation and improve usability, they were ultimately deprioritized because of budget constraints and practical concerns related to battery charging and long-term maintenance within the manufacturing environment. As a result, the final design emphasized mechanical simplicity, reliability, and cost-effectiveness while maintaining the potential for future electronic enhancements.

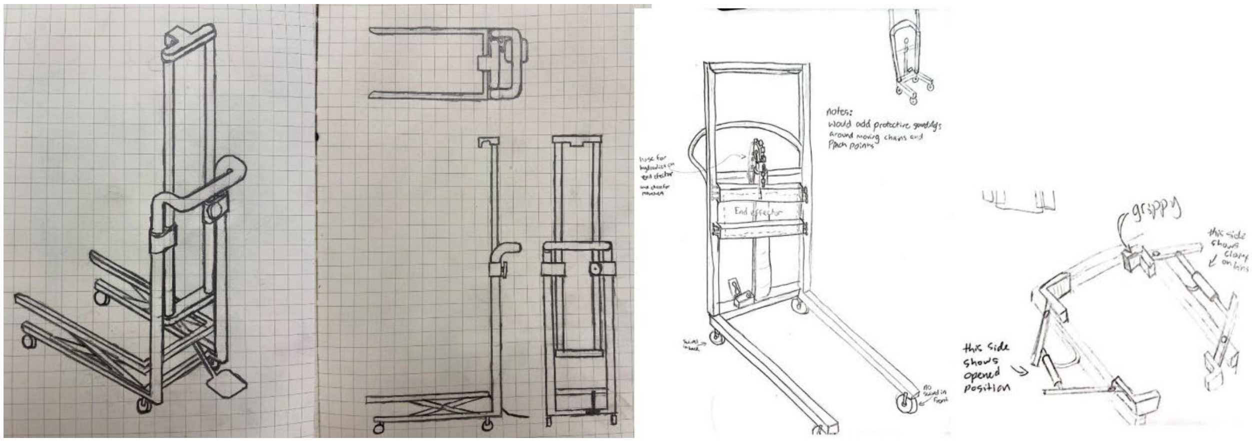


Figure 3. Design Concepts

4.8 Material Selection & Design Optimization

ASTM A36 steel was chosen for its high strength-to-cost ratio (yield 36 ksi) and fatigue endurance limit (~30 ksi at 10^7 cycles). Fastened joints replaced welds to enable modularity and maintenance. A protective powder-coat finish improved corrosion resistance and visibility.

SolidWorks 2024 and Simulation were used for design and analysis; Microsoft Planner supported scheduling; and the ET machine shop provided machining, welding, and assembly capabilities. Design refinements included adjustable ergonomic handles, dual-spring foot-pedal actuation, and EPDM rubber contact strips to prevent slippage.

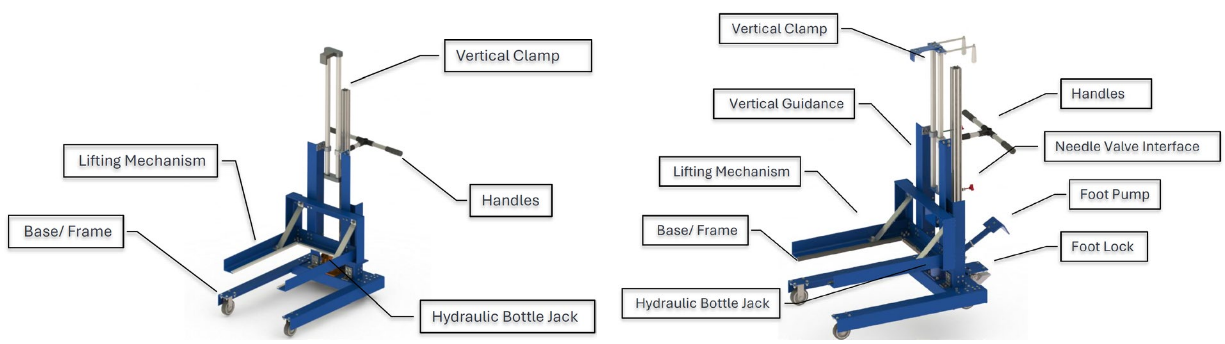


Figure 4. Earlier Concept SolidWorks Model and Handle Assembly. (Left) Revised Concept SolidWorks Model (Right)

Simulation and Validation

FEA simulations confirmed safe operation under 600 lb. load:

- Max von Mises stress = 6 ksi (< 36 ksi limit)
- Deflection = 0.02 in (at fork tips)
- Factor of Safety = 5.2
- Predicted fatigue life > 50,000 cycles

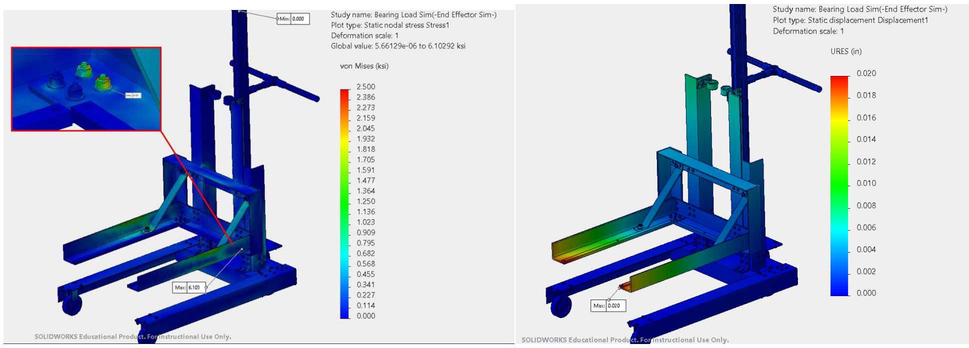


Figure 5. Von Mises Stress and Displacement Plots.

4.9 Economic Analysis

The finalized bill of materials resulted in a total cost of $1,110 per cart, reflecting an increase from the prior term estimate of $900 as the design was completed and all components were procured. Due to schedule constraints, the number of carts delivered was reduced from three to two, increasing the allowable per-unit budget to $1,500 and leaving the project under budget by $389 per cart.

4.10 Prototype Fabrication and Assembly

Figure 6. Fork-Dolly Test Assembly (Left) 1st Prototype (Middle) Final Prototype (Right)

Parts were fabricated in the ET machine shop. Two prototypes built to validate form, fit, and function. Following painting and reassembly of the steel components, a second prototype was constructed incorporating the foot pump and vertical clamping assemblies. Iterative testing identified several mechanical refinements, including relocation of bearing plate holes to eliminate interference, optimization of the hydraulic jack starting height, and improvement of pedal return through the addition of a second spring. The final prototype incorporated a custom needle valve interface and a positive locking mechanism for the vertical clamp. Subsequent testing confirmed reliable lifting, transport, and maneuverability, marking the successful completion of the physical deliverables for the project.

4.11 Ergonomic Validation

Ergonomics was a central focus of the cart design, driven by deficiencies observed in existing material-handling dollies that required operators to work close to floor level with short pull handles, resulting in awkward postures and increased physical strain. These limitations often led operators to bypass the dollies. To address these issues, the proposed cart was designed to be pushed rather than pulled and incorporated adjustable handle heights with contoured vinyl grips to accommodate a range of operators and improve comfort. Most critically, the cart eliminates repeated manual lifting by using a foot-actuated hydraulic mechanism, allowing operators to raise and lower bin stacks using controlled leg motion instead of complex upper-body movements.

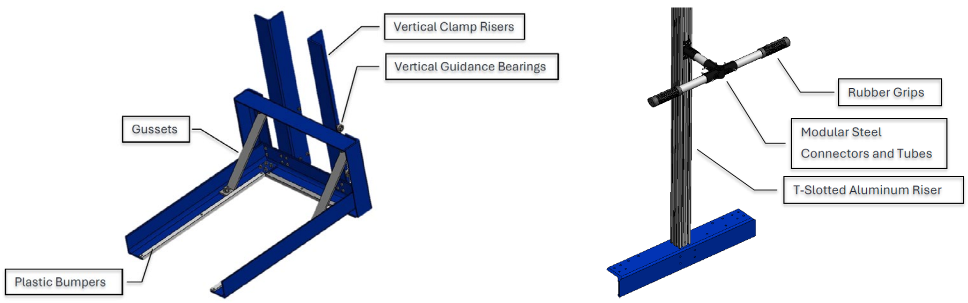


Figure 7. Red7signed End Effector (Left) and Handle Assembly (Right)

4.12 Performance Testing

Post-prototype testing confirmed that the final cart design met or exceeded the majority of established design parameters. The cart width aligned with OSHA-compliant 36-inch aisle requirements, ensuring maneuverability within standard walkways. Actuation forces were well below established health and safety limits, with the foot pump requiring only 5.4 lb. and manual clamp operation requiring approximately 12 lb., validating the ergonomic effectiveness of the design. Structural analysis indicated a factor of safety higher than necessary, suggesting opportunities for future optimization through material reduction and component downsizing.

Both carts met all sponsor specifications, achieving superior ergonomic and safety performance. Measured pedal forces, lifting range, and structural deflection aligned with FEA predictions. Operators at SouthCo, Inc Manufacturing reported reduced strain and smoother handling compared with legacy dollies.

5. Educational Outcomes and Assessment

5.1 Project Performance Evaluation Indicators (PEIs).

The Performance Evaluation Indicators (PEIs) are structured to reflect the progressive development of student competencies over the three-quarter senior design sequence. During the Fall term, assessment emphasizes problem identification, background research, target specifications, and concept generation, with higher weighting placed on literature review, market and patent analysis, and formulation of alternative solutions. The Winter term shifts focus toward analytical rigor and design maturity, assessing refinement of alternative concepts, application of decision matrices, system modeling, and progress toward a feasible solution informed by stakeholder feedback. In the Spring term, assessment concentrates on final solution quality, technical justification, and engineering judgment, with increased weighting on validated specifications, finalized designs, and conclusions drawn from analysis and experimentation. Collectively, the PEI framework ensures a balanced and systematic evaluation of student performance, reinforcing a year-long transition from problem formulation to validated, industry-ready engineering solutions.

Table 2. Project Performance Evaluation Criteria as progresses from fall term to final spring term [15]. (Partial list)

Performance Evaluation Indicator (PEI)	Term		
	Fall	Winter	Spring
	Proposal	Progress	Final
PEI 1: Provides clear and concise description of the unmet needs, and/or opportunity for the project, material abundantly supported the topic	15% of grade Full research: lit. survey, patent, search, market analysis	5% of grade Discussion with stakeholders	5% of grade
PEI 2: Well defined problem statement, properly delineated extensive final target specifications, and performance objectives, aligned with solution	10% of grade Just the initial target specification	5% of grade Performance objectives Design specification	5% of grade Final specs
PEI 3: The solution decision is supported through well analyzed and realistic alternative concepts to solve the problem, based on specifications and customer needs	10% of grade Two or more feasible and realistic concepts to solve the problem, based on target specifications and customer needs	10% of grade Refinement of alternative concepts	10% of grade Research of alternative concepts
PEI 4: The solution is described clearly, in a well-organized manner with supporting arguments and data, and presents relevant material that motivates their effort	10% of grade Focus on concept selection process, decision matrices, function decomposition	15% of grade Decision matrices to analyze and select solutions to systems, subsystems, and critical components	15% of grade Final solution
PEI 5: Appropriate detailed modelling of the engineering system/product (methodology, theory, approach)	10% of grade	15% of grade Description of the progress towards a solution	15% of grade
PEI 6: Solution is feasible and is justified appropriately and is satisfying target specifications and stakeholders' needs: cost-effective solution to the problem or opportunity	10% of grade	10% of grade	10% of grade
PEI 7 Team demonstrated a strong ability to develop and conduct experimentation, analyze, and interpret data in the context of their solution Appropriate modelling of the engineering system/product (methodology, theory, approach)	10% of grade Modelling of engineering systems	15% of grade Appropriate design of the engineering system/product (methodology, approach – applied or theoretical	10% of grade
PEI 8: Team demonstrated sound engineering judgment to draw conclusions related to the development of the product	10% of grade	10% of grade	15% of grade

6. Assessment Analysis and Performance Trends

Assessment of student performance in this industry-sponsored senior design project was conducted using Performance Evaluation Indicators (PEIs) aligned with ABET-ETAC Student Outcomes. The assessment framework was designed to capture both technical and professional skill development over the course of the three-term capstone sequence (Fall 2024, Winter 2025, and Spring 2025). Evaluation data were derived from faculty assessments, industry mentor feedback, written reports, oral presentations, milestone design reviews, and peer evaluations.

6.1 Assessment Framework and Data Collection

Each PEI was evaluated separately for oral and written deliverables to distinguish between students' ability to communicate technical content verbally and their proficiency in professional engineering documentation. Scores were normalized to percentages to facilitate longitudinal comparison across academic terms. This approach enabled tracking of individual PEIs and identification of areas of greatest growth, providing both formative feedback during the project and summative evidence for program-level assessment.

6.2 Overall Performance Progression

The assessment results reveal a consistent upward trend across all PEIs throughout the academic year. Average performance improved steadily from the Fall term, when students were primarily engaged in problem definition and conceptual design, to the Spring term, when fabrication, testing, and validation activities dominated. No regression was observed in any PEI category, indicating sustained skill development and effective team functioning.

Overall, PEI averages increased by approximately 11 percentage points from Fall to Spring. This improvement reflects the cumulative impact of iterative design, repeated sponsor interactions, and structured milestone reviews. The most pronounced gains occurred between the Winter and Spring terms, coinciding with hands-on prototyping, performance testing, and final sponsor presentations.

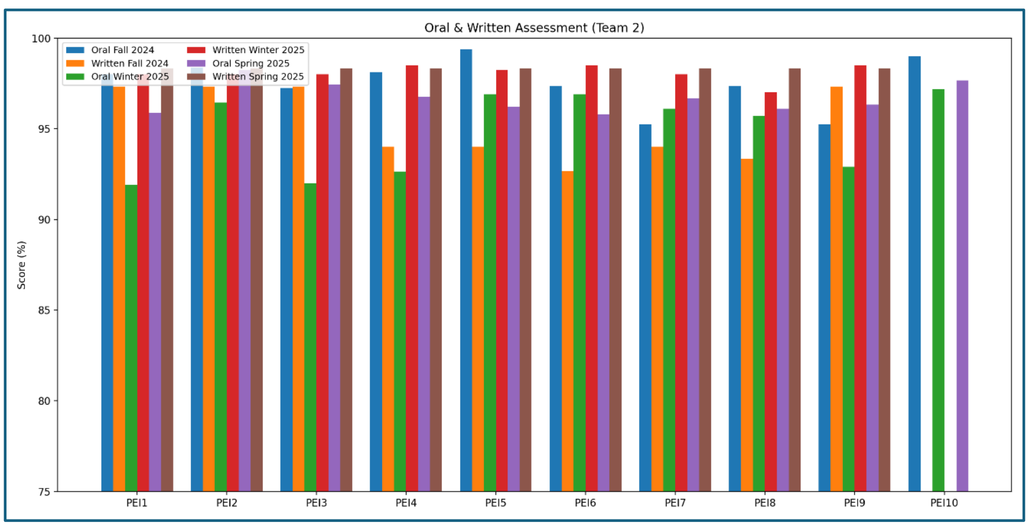


Figure 8. The Team's oral/written assessment from Fall 24 to Spring 25 (PEI Progression)

6.3 PEIs Demonstrating the Greatest Improvement

While all PEIs showed positive trends, several indicators exhibited notably higher rates of improvement:

Technical Depth and Design Justification (PEI5).
This PEI demonstrated one of the largest net gains over the project duration. Early

assessments indicated that students relied heavily on descriptive explanations of design decisions. By the Spring term, students consistently justified design choices using finite element analysis results, material properties, ergonomic considerations, and safety standards. This progression indicates increased engineering judgment and confidence in applying analytical tools to real-world problems.

Integration of Analysis, Testing, and Results (PEI7).
Significant improvement was observed in students' ability to integrate simulation, experimental testing, and design iteration. Initial assessments showed limited correlation between analytical predictions and physical test results. In later terms, students demonstrated a strong ability to compare simulation outcomes with load testing data, identify discrepancies, and implement design refinements. This PEI reflects successful development of systems thinking and evidence-based decision-making.

Professional Communication and Documentation (PEI8).
PEI8 showed substantial improvement, particularly in written assessments. Early reports required extensive faculty guidance to meet professional standards. By the final term, student documentation—including CAD drawings, bills of materials, operator manuals, and final reports—demonstrated clear organization, technical accuracy, and appropriate use of engineering terminology. This trend underscores the effectiveness of iterative documentation requirements and sponsor-facing deliverables in strengthening professional communication skills.

Moderate and Sustained Improvement Areas

PEIs associated with foundational technical skills and teamwork (PEI1–PEI3) exhibited steady but more modest gains. These indicators were already relatively high in the Fall term, suggesting that students entered the capstone sequence with a strong technical foundation. Continued improvement in these areas reflects refinement rather than initial skill acquisition.

Oral Versus Written Assessment Trends

A comparison of oral and written PEI scores reveals distinct developmental patterns. Oral communication scores were generally strong in the early stages of the project, reflecting students' comfort with informal technical discussions. Written assessment scores, however, showed larger net improvements over time, particularly in PEIs related to technical depth and documentation quality.

This divergence suggests that while verbal communication skills benefited from frequent presentations and design reviews, technical writing skills improved most through repeated feedback cycles and formal reporting requirements. The combined assessment approach provides a more comprehensive view of student learning than either modality alone.

Implications for Engineering Technology Education

The assessment trends observed in this project support the effectiveness of industry-sponsored, interdisciplinary capstone experiences in Engineering Technology education. PEIs associated with higher-order competencies—such as analysis integration, design justification, and professional documentation—showed the greatest improvement, indicating that authentic industrial constraints and iterative design processes are particularly effective at fostering advanced learning outcomes.

From an accreditation perspective, the structured use of PEIs provides direct evidence of student achievement aligned with ABET ETAC outcomes and supports continuous improvement initiatives. The results also reinforce the value of longitudinal assessment across multiple academic terms, as many critical competencies emerge most strongly during later stages of complex design projects.

6.4 Industry-Sponsored vs. Faculty-Developed Project Comparison

To better understand the impact of industry-sponsored capstone projects on student learning outcomes, performance was analyzed across grouped Performance Evaluation Indicators (PEIs), categorized into technical knowledge, design and analysis, system integration, communication, and professional skills. **Figure 9** presents a comparison of average Spring term scores between industry-sponsored (5 projects) and faculty-developed (5 projects) teams across the 2023 and 2024 cohorts.

Industry-sponsored teams demonstrate consistently higher performance across most PEI categories, with the most pronounced differences observed in:

- Integration & Experimentation (PEI7)
- Professional Communication (PEI8)
- Professional Practice (PEI9–PEI10)

These areas represent higher-order engineering competencies, including system integration, design validation, and professional engagement. The improved performance suggests that exposure to real-world constraints—such as safety requirements, budget limitations, and stakeholder expectations—enhances students' ability to move beyond conceptual design toward validated engineering solutions.

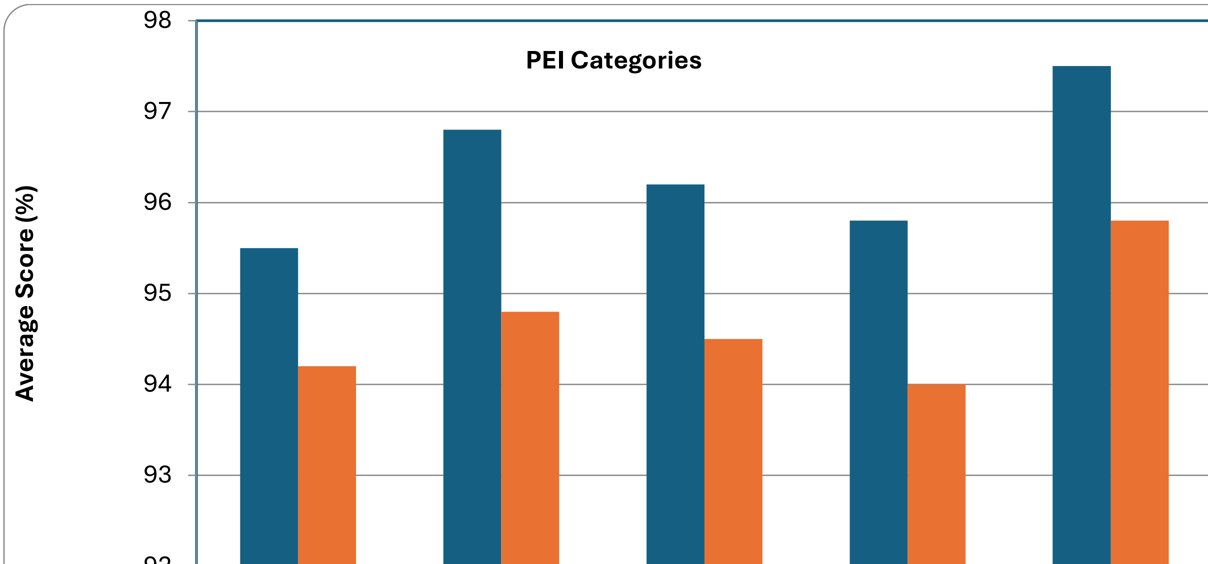
In contrast, differences in technical knowledge (PEI1–PEI3) are relatively small, indicating that both groups achieve comparable mastery of foundational concepts. This is expected, as these competencies are primarily developed through prior coursework rather than the capstone experience itself.

Moderate improvements are also observed in communication-related PEIs, where industry-sponsored teams produce more structured reports and professional presentations. This likely reflects increased accountability associated with external stakeholder interaction.

Professional skills show high performance across both groups, with slightly greater consistency among industry-sponsored teams. This suggests that industry engagement reinforces teamwork, responsibility, and adherence to professional expectations.

Overall, the results indicate that the primary advantage of industry-sponsored capstone projects lies in strengthening applied engineering competencies—particularly in integration, validation, and real-world problem solving—rather than in improving baseline technical knowledge.

While the differences are consistent, they are not large, and all teams achieved high overall performance. This suggests that the capstone structure itself is effective, with industry sponsorship providing an additional layer of rigor and realism that enhances student outcomes.



	Technical Knowledge	Design & Analysis	System Integration	Communication	Professional Skills
Industry Avg	95.5	96.8	96.2	95.8	97.5
Faculty Avg	94.2	94.8	94.5	94	95.8

Figure 9. Comparison of Industry-Sponsored and Faculty-Developed Capstone Projects Across PEI Categories (Normalized Scores, Spring 23 and Spring 24)

6.5 Response to Research Question

To address the research question, the results indicate that participation in an industry-sponsored, interdisciplinary capstone project is associated with enhanced development of higher-order engineering competencies compared to traditional faculty-developed experiences.

PEI trends over the three-quarter sequence show clear gains in design justification, system integration, and professional communication, particularly in later project stages. These findings are reinforced by category-level comparisons (Figure 8) and cohort-level analysis (Figure 9), which show consistently higher performance among industry-sponsored teams in competencies requiring application, synthesis, and validation.

Differences in foundational technical knowledge remain minimal, while the most meaningful improvements occur in areas influenced by real-world constraints. Industry-sponsored teams are required to operate within defined requirements, stakeholder expectations, and deliverable accountability, promoting deeper learning and stronger professional readiness.

These results should be interpreted as preliminary due to the limited sample size; however, the consistency of trends across cohorts suggests a meaningful relationship between industry engagement and student development. Future work will expand the dataset to further validate these findings.

7. Conclusions

This study highlights that the primary educational value of industry-sponsored capstones lies in the integration of real-world constraints that require students to synthesize analysis, design, and decision-making. These experiences play a critical role in developing higher-order competencies essential for modern Engineering Technology practice.

The ergonomic cart project illustrates this impact. Technically, the team delivered a safe, cost-effective, and durable solution. Educationally, students demonstrated measurable gains in teamwork, documentation, and design integration, supported by PEI-based assessment.

Comparative analysis across Spring 2023 and Spring 2024 cohorts, including 10 teams with 5 industry-sponsored projects, indicates stronger performance in advanced competencies—particularly system integration, design justification, and professional communication—among industry-sponsored teams. While overall performance remains high across all teams, the consistent gains in these areas suggest that industry engagement adds meaningful rigor and realism to the learning experience.

By integrating project-based learning with authentic industrial collaboration, the capstone experience strengthens ABET-aligned outcomes and better prepares graduates for the demands of modern manufacturing environments.

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