



Balancing Academic Standards and Industry Demands: Refining Real-world Problems for an Engineering Capstone Design Course

Syed Hassan, Syed Ahmad Helmi^{a,b}, Ramsey, Aaron^a, Zehrung, Craig Allen^a, Kothari, Prathyush Dinesh^a, Lumbera, Maxell Pasia^b, Mohd Yusof, Khairiyah^b
*School of Industrial Engineering, Purdue University, West Lafayette, IN 47907, USA^a,
School of Engineering Education, Purdue University, West Lafayette, IN 47907, USA^b
Corresponding Author's Email: ssyedhas@purdue.edu*

ABSTRACT

CONTEXT

Engineering instructors incorporate team-based real-world industrial problems into capstone courses to help their students transition from classroom learning to practical application. However, the initial versions of industry-supplied problems may not always align with the requirements of a capstone course, due to the differing contexts of industry and academia.

PURPOSE

This work-in-progress paper investigates the development and refinement of real-world industrial problems used in a senior Industrial Engineering capstone course at a large Midwestern public university. It examines how engineering instructors and industry partners collaboratively shape initial problem statements to align with academic standards and learning objectives, ensuring students gain meaningful, practice-oriented experience.

APPROACH

Using project data, the study analyzed the evolution of these problems through student proposals, compared them against Jonassen's typology of problem-solving, and evaluated instructional strategies based on Woods' engineering design framework.

ACTUAL OUTCOMES

Findings suggest that most problems are ill-structured design challenges, requiring iterative adaptation to strike a balance between industry relevance and pedagogical rigor.

CONCLUSIONS

The study highlights the importance of early collaboration between faculty and industry in delivering equitable and impactful learning experiences, with implications for enhancing student readiness for professional practice. Future research could explore the short-term impacts of these strategies on student learning and the long-term implications on their professional readiness.

KEYWORDS

Capstone Design, ill-structured problems, real-world industrial problems.

Introduction

The Industrial Engineering (IE) Capstone Design Project is not merely an academic requirement; it is a defining experience that bridges conceptual mastery with professional execution. This immersive project places students at the heart of real-world complexity, challenging them to address pressing industrial problems sourced directly from industry partners. Within a structured and iterative framework, students apply IE methodologies to analyze, simulate, and optimize systems in logistics, manufacturing, human factors, and operations research. The result is a set of implementable proposals that reflect intellectual rigor, methodological depth, and a sophisticated understanding of industrial ecosystems (Martínez León, 2019; Abdullah, 2021). Capstone projects in IE are widely recognized as the point where academic theory meets professional practice. These experiences allow students to demonstrate competencies in systems modeling, operations analysis, stakeholder engagement, and data-driven decision-making. Beyond academic rigor, they often deliver tangible value to industry partners, fostering innovation and bridging institutional knowledge with operational needs (Badir et al., 2023; Abdullah, 2021).

Background of the Study

Capstone design courses represent the pinnacle of undergraduate engineering education, serving as a culminating experience where students integrate their accumulated knowledge into a comprehensive project that reflects real-world professional practice. These courses are grounded in academic rigor, challenging students to demonstrate proficiency in engineering principles, analytical reasoning, and systematic problem-solving. However, the increasing involvement of industry partners in capstone programs has introduced a new dimension: the need for projects to reflect real-world relevance, market constraints, and practical deliverability. This dual expectation creates a tension between academic standards and industry demands. Academic institutions prioritize learning outcomes, documentation, and theoretical depth, while industry stakeholders often value agility, innovation, and results that can be implemented or commercialized. As a result, educators face the challenge of curating and refining project problems that satisfy both domains without compromising educational integrity or industrial applicability. Moreover, real-world problems presented by industry are often ill-defined, open-ended, and subject to evolving requirements, the characteristics that can be pedagogically rich but logistically complex. Students may struggle to navigate ambiguity, manage stakeholder expectations, and balance technical feasibility with business constraints. Instructors, meanwhile, must ensure that such projects remain feasible within the time frame, ethical, of suitable complexity, and aligned with accreditation standards.

Final-year IE Capstone Design projects are structured to meet accreditation standards set by ABET and the Washington Accord, both of which emphasize real-world engineering experience. ABET requires students to solve complex, open-ended problems under realistic constraints, such as economic, environmental, and ethical considerations, while demonstrating teamwork, communication, and proficiency in modern tools (Schmidt & Conrad, 2012). Similarly, the Washington Accord outlines graduate attributes, including problem analysis, sustainable design, and multidisciplinary collaboration, ensuring that graduates are prepared for global engineering practice (International Engineering Alliance, 2013).

Community-based and industry-partnered capstone projects further enhance experiential learning. For example, Mittal et al. (2020) describe how IE students collaborated with a nonprofit food bank to improve logistics and distribution using IE tools, demonstrating the societal impact and technical relevance of such projects. Together, these frameworks and studies affirm that IE capstone projects can be transformative experiences. They prepare students to become strategic problem solvers equipped with the practical skills and global perspective needed to lead innovation in competitive industrial environments. At Purdue University's Edwardson School of Industrial Engineering, students have undertaken

multifaceted initiatives that address real-time industrial challenges, including strategic supply chain cost optimization, predictive maintenance protocols, advanced facility layout design, and performance dashboard development to enhance decision support (Purdue University, 2025). Similarly, the University of Oklahoma highlights a robust portfolio of capstone projects that address lean implementation in healthcare delivery systems, logistical enhancements in aerospace operations, and the standardization of warehouse protocols (University of Oklahoma, 2025). At Georgia Tech, Industrial Engineering seniors undertake capstone projects that integrate data analytics, systems engineering, and process optimization to address complex problems for industry sponsors, ranging from improving manufacturing efficiency to redesigning service systems (Georgia Institute of Technology, 2025).

Meanwhile, at the National University of Singapore, final-year students in the Innovation & Design Programme pursue interdisciplinary projects that emphasize independent inquiry, design thinking, and entrepreneurial development, often culminating in prototypes and venture pitches through the EDIC Project Showcase (National University of Singapore, 2025). Collectively, these examples illustrate the transformative power of capstone projects in cultivating agile, solution-oriented engineers primed to lead in today's complex industrial landscape.

This paper addresses the critical need to refine real-world problems for capstone design courses to balance academic expectations with industry relevance. It explores frameworks for problem selection, stakeholder engagement, and project scoping that promote meaningful learning while delivering value to external partners. By examining case studies and best practices, the paper aims to provide actionable insights for educators seeking to enhance the quality and impact of their capstone programs.

Research Questions

This study examines the integration of real-world industrial challenge problems into IE capstone design courses. It explores the nature of problems assigned to students, the methods used to align these challenges with core IE principles and academic objectives, and the role of direct industry engagement, such as site visits and stakeholder interactions, in deepening students' understanding. Additionally, the study examines instructional strategies employed by faculty to ensure that these projects reflect the practical and pedagogical standards expected of a robust IE capstone experience.

The following guiding inquiries anchor this study:

1. What types of real-world industrial challenge problems are assigned to the IE students?
2. In what ways can these problems be effectively aligned with IE principles and academic learning objectives?
3. What strategies do engineering instructors implement to ensure that these problems align well with the characteristics of a practical IE capstone design problem?

Underpinning Principles

Final-year engineering capstone design projects are grounded in core principles that reflect both academic rigor and professional relevance. Central to these projects is the integration of knowledge and skills acquired throughout the engineering curriculum. Students apply mathematics, science, and discipline-specific engineering principles to solve complex, open-ended problems that mirror real-world challenges. These projects encompass the entire design cycle, from problem definition and conceptualization to prototyping, testing, and refinement, thereby encouraging innovation, creativity, and practical feasibility (Berry, Huang, & Exter, 2024).

Teamwork is vital, as students collaborate in multidisciplinary groups, thereby developing leadership, communication, and interpersonal skills essential to professional practice. Mostafapour and Hurst (2020) highlight how effective teamwork processes directly influence perceived team success in capstone environments. Ethical responsibility and societal impact are also key considerations, requiring students to address safety, sustainability, and professional conduct in their solutions. Effective communication is critical, as students must present their work to both technical and non-technical audiences through reports, presentations, and demonstrations. Project management skills are cultivated through planning, budgeting, and resource allocation, preparing students for industry demands. Capstone projects also promote systems thinking and lifelong learning, encouraging students to reflect on their experiences and recognize the importance of continuous professional development. These principles align with global accreditation standards, such as ABET and the Washington Accord, ensuring that graduates are well equipped for engineering practice in a rapidly evolving world (Biney, 2007; Watkins, 2022).

The Capstone Design Project in IE is grounded in foundational pillars that guide innovative, systems-oriented problem-solving. At the forefront is *Systems Thinking*, which enables holistic analysis of interdependent components within complex operational ecosystems, fostering solutions that account for dynamic interactions and long-term impacts (Stermann, 2000). *Lean Manufacturing* drives efficiency by eliminating waste and optimizing value streams, ensuring that engineered processes deliver maximum utility with minimal resource consumption (Womack & Jones, 1996). *Simulation and Modeling* empower students to conduct predictive analysis and performance testing through digital representations, enhancing decision-making under uncertainty (Law & Kelton, 2014). *Human Factors and Ergonomics* ensure that system designs are attuned to human capabilities, safety, and usability, promoting user-centered engineering outcomes (Sanders & McCormick, 1993). Complementing these is *Data Analytics*, which enables the extraction of actionable insights from complex datasets, supports evidence-based decision-making, and validates engineering solutions through statistical and computational techniques. This data-driven approach is increasingly central to capstone projects, reinforcing the discipline's commitment to intelligent, adaptive, and impactful engineering design. These principles are not merely theoretical; they are actively deployed throughout the capstone lifecycle, empowering IE students to engineer solutions that are both technically sound and human-centered.

David Jonassen's seminal work on problem typology laid the foundation for understanding how learners engage with different kinds of problems in educational settings. In his influential paper, *Toward a Design Theory of Problem Solving*, Jonassen (2000) proposed a framework that categorizes problems into eleven distinct types, ranging from well-structured algorithmic tasks to ill-structured dilemmas and design challenges. He emphasized three key dimensions (structuredness, complexity, and domain specificity) as critical factors that influence how problems should be approached and taught. Jonassen's framework has been widely adopted in instructional design, particularly for tailoring learning environments to match the cognitive demands of specific problem types.

Building on Jonassen's foundation, Johannes Strobel has expanded the conversation by introducing the concept of compound problem solving, which recognizes that real-world problems often consist of multiple, interwoven problem types. Strobel and colleagues (Strobel, Wang, & Weber, 2013) identified *transition problems*, the cognitive and procedural challenges learners face when shifting between problem types within a compound scenario. This insight enhances Jonassen's typology by acknowledging the dynamic nature of authentic problem solving, especially in STEM and engineering education.

Moreover, Strobel has been a leading advocate for Problem-Based Learning (PBL), emphasizing the importance of authenticity, collaboration, and interdisciplinary thinking. His research highlights the importance of instructional environments that reflect the complexity and ambiguity of real-world challenges (Strobel & Van Barneveld, 2009). By integrating empirical findings from workplace settings, Strobel has helped bridge the gap between theoretical

models and practical application, making Jonassen's framework more actionable in contemporary educational contexts.

Together, Jonassen and Strobel offer a complementary lens on problem solving: Jonassen provides the structural taxonomy. At the same time, Strobel injects realism and fluidity, pushing educators to design learning experiences that reflect the multifaceted nature of human inquiry.

Donald R. Woods' problem-solving approach emphasizes structured thinking, teamwork, and system-level analysis. His method begins by identifying pain points through the examination of how components within a system interact, revealing inefficiencies, bottlenecks, or misalignments (Woods, 1983). This systems perspective is essential in engineering design, especially in IE Capstone Projects, where real-world problems are addressed using IE principles and tools. A key focus in Woods' framework is aligning industrial problems with IE knowledge, principles, and tools to ensure solutions are efficient, scalable, and sustainable. For example, in a manufacturing setting facing delays, engineers might use value stream mapping and process flowcharts to visualize operations, followed by DMAIC to guide structured improvement. Tools like Pareto analysis, root cause diagrams, and regression analysis help prioritize and validate issues.

Modern IE integrates data analytics and emerging technologies to enhance problem-solving. Platforms such as Power BI, Python, and Tableau support data visualization and statistical modeling, whereas simulation tools such as FlexSim and AnyLogic enable virtual testing of solutions. Technologies like IoT sensors, machine learning, and automation systems further enable predictive maintenance and real-time optimization (Campilho & Silva, 2023; Das, 2024). Recent studies highlight the impact of these tools. Saha (2024) demonstrated that Kaizen principles and IE techniques, such as time-motion studies and poka-yoke, significantly reduced production time, increased throughput, and reduced defects. Similarly, Das (2024) reviewed how Six Sigma, Lean, and operations research methods optimize productivity across industries. Campilho and Silva (2023) emphasized the role of robotics and automation in enhancing flexibility, precision, and efficiency in Industry 4.0 environments.

By combining Woods' structured methodology with modern IE tools and technologies, engineers can effectively identify system-level challenges, analyze data, and implement effective solutions, preparing them to lead innovation and continuous improvement in dynamic industrial settings.

Methodology

The methodology of this study is based on the research question of how to ensure the alignment between real-world industrial problems and the IE knowledge and principles. Therefore, the study focuses on applying engineering principles, particularly IE principles, to solve complex, open-ended problems under realistic constraints, including economic, environmental, and ethical considerations. It began with answering the question: What types of engineering problems are assigned to students?

The following are the detailed learning objectives (LOs) of the IE Capstone Design for the institution. Upon successful completion, the student should be able to:

- 1 Perform project management, including writing a project proposal, scheduling and allocation of effort, budgeting, performance monitoring, and evaluation of a solution's effectiveness.
- 2 Be able to interact with an external client outside of the classroom to deliver industrial engineering solutions to significant problems in manufacturing, healthcare, city and state governments, or other settings.
- 3 Conduct economic analysis and justification of proposed solutions in a real-world setting.
- 4 Effectively present engineering analyses, including written reports, oral presentations, and team website.

- 5 Demonstrate effective teamwork and collaboration with group members on a single project over the entire semester.
- 6 Use web-based technology to distribute effort and collaborate remotely with an external client.
- 7 Understand the diversity of worldviews, values, behaviors, and communication methods, and their influence on problem solving, data conceptualization, methodologies, and solutions.
- 8 Feel confident in their abilities to use concepts learned during their time as undergraduate students in Industrial Engineering, to solve real-world problems and provide expert advice to industry executives.
- 9 Gain an in-depth knowledge of the requirements of analyzing real-world problems, analysis, and critical thinking, to provide feasible and affordable solutions.

Based on these LOs, LOs 2, 8, and 9 are closely related to these research questions. This study will not examine other LOs, such as teamwork, presentation, or ethics. To answer these questions, this study used data taken from Fall 2024 and Spring 2025. In total, 53 industrial projects are assigned to 5 students each.

Proposed Data Gathering and Solution Generations

The following discussion will explain how the research questions will be answered.

Research Question 1:

What types of real-world industrial challenge problems are assigned to the IE students?

In an IE Capstone Design Project, students typically work on problems sourced directly from industry. While these problems are inherently industrial in nature, their educational value depends on how well they support learning objectives and challenge students to apply core IE principles. Table 1 presents the Yes/No Problem Analysis Rubric, which provides a structured approach to evaluating this alignment.

Table 1: Problem Analysis Rubric

Aspect	Question	Yes/No
Structuredness	Is the problem open-ended with multiple valid solutions?	
Complexity	Does the problem involve multiple variables or interdependent factors?	
Cognitive Transitions	Does the problem require shifting between different types of thinking (e.g., analytical, creative, procedural)?	
Authenticity	Is the problem realistic and relevant to real-world situations?	
Disciplinary Relevance	Does solving the problem require knowledge from one or more academic or professional domains?	
IE Integration	Does the problem specifically require industrial engineering principles, methods, or tools?	

The rubric includes six dimensions: structuredness, complexity, cognitive transitions, authenticity, disciplinary relevance, and industrial engineering integration. Even when problems originate from industry, not all are equally open-ended or complex. Structuredness evaluates whether the problem allows for multiple valid solutions, encouraging innovation. Complexity ensures that the problem involves interacting variables or systems, reflecting real-world decision-making processes. Cognitive transitions assess whether students must shift between analytical, procedural, and strategic thinking: skills essential in professional practice.

Authenticity confirms the problem's relevance to actual industrial contexts, which is typically a strength in capstone projects. Disciplinary relevance checks whether the problem draws on multiple fields, such as data analytics, ergonomics, or sustainability. Finally, industrial engineering integration ensures that the problem requires the direct application of IE methods, such as simulation, optimization, or lean principles. This rubric builds on the work of Jonassen (2000), who emphasized the importance of ill-structured problems for deep learning, and Strobel and van Barneveld (2009), who highlighted the value of authentic, domain-rich challenges in problem-based learning. By applying this rubric, instructors can better evaluate whether an industrial-based problem is not only realistic but also pedagogically robust and aligned with the goals of an IE capstone experience.

Research Question 2:

In what ways can these problems be effectively aligned with IE principles and academic learning objectives?

Figure 1 below illustrates the overall process of aligning industrial problems with engineering principles, particularly IE. It unfolds as a structured engagement between academia, industry, and students.

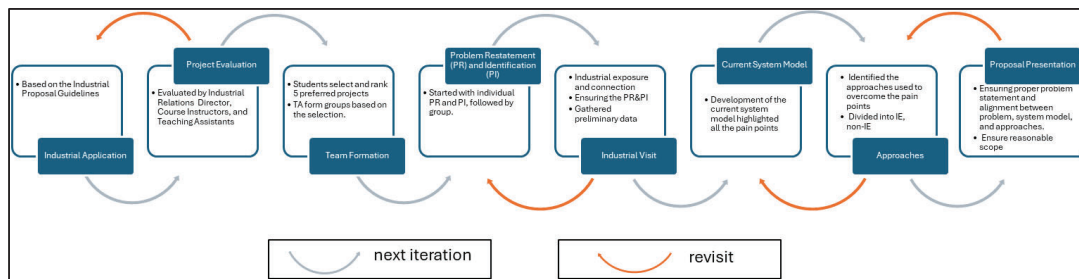


Figure 1: Process of Alignment between Industrial Problems and Engineering Principles

The process for developing and presenting an industrial project proposal begins with preparing an application based on established guidelines for industrial project proposals. Projects are evaluated by the Industrial Relations Director, course instructors, and teaching assistants. Students then select and rank their preferred projects, after which teams are formed. The next step involves problem restatement and identification (PR/PI), starting with individual work and followed by group refinement. This stage may require revisiting the initial application and project evaluation to ensure clarity and alignment. An industrial visit follows, providing real-world exposure, confirming the PR/PI, and enabling the collection of preliminary data. Insights from the visit may prompt a revisit to the PR/PI stage for refinement. Teams then develop a current system model that highlights pain points, which may also lead to revisiting earlier steps to confirm accuracy. Approaches to address these pain points are identified and categorized into IE and non-IE methods, with possible revisits to the system model or PR/PI for consistency. The process culminates in a proposal presentation that ensures a clear problem statement, strong alignment between the problem, system model, and approaches, and a reasonable scope, while incorporating any necessary revisions from earlier stages.

Research Question 3:

What strategies do engineering instructors implement to ensure that these problems align well with the characteristics of a practical IE capstone design problem?

To ensure effective alignment, engineering instructors guide students through a structured, multi-stage process comprising: (1) Problem Restatement and Identification, (2) Current System Modeling, and (3) Problem-Solving Approaches.

In Stage 1, students are required to restate the problem clearly and concisely, drawing from the detailed information provided in the industry's problem catalogue. They then identify the

problem using the KNL framework: *what they Know*, *what they Need* to know, and the *Learning issues*. The “need to know” and “learning issues” represent the first layer of problem alignment, approached through three conceptual lenses:

1. IE Approaches (e.g., simulation, facility layout, inventory analysis),
2. Other Engineering Approaches (e.g., software implementation, sensor integration),
3. Non-Engineering Approaches (e.g., organizational policy changes, workforce training programs).

In Stage 2, students develop a current system model that maps detailed operational flows. Within this model, they identify pain points that must correspond with the restated problem, thus constituting the second alignment. Subsequently, students propose solution strategies grounded in IE principles, forming the third alignment between industrial needs and academic expectations.

Following modeling and ideation, teams conduct industrial site visits to validate assumptions, observe operational dynamics, and collect firsthand data. These visits often lead to a reassessment of the problem framing and methodology, marking the fourth alignment.

Finally, students prepare and present formal project proposals to instructors and, where applicable, industry stakeholders. These presentations serve as both evaluative checkpoints and developmental milestones. Feedback received during this phase is integrated into the final deliverables, representing the fifth and final alignment, hence ensuring that the project remains academically rigorous while addressing real-world industrial challenges.

In summary, to ensure the problem alignment, this Capstone Design Project unfolds through a structured, multi-phase methodology:

- 1 Problem Sourcing and Evaluation: Industry partners submit operational challenges, which are rigorously vetted by faculty to ensure pedagogical alignment and feasibility.
- 2 Team Formation and Problem Restatement: Students self-select into teams based on interest and skillset, then individually and collectively reframe the problem to establish a shared understanding.
- 3 System Modeling: Teams conduct in-depth analyses using tools such as process mapping, stakeholder matrices, and performance benchmarking.
- 4 Methodology Identification: Proposed solutions are categorized into IE-centric approaches, cross-disciplinary engineering strategies, and non-engineering interventions.
- 5 Industrial Visit: Site visits provide critical context, enabling teams to validate assumptions, observe operations firsthand, and gather empirical data.
- 6 Proposal Development and Presentation: Students synthesize findings into formal proposals, which are presented to faculty and industry stakeholders for critique and refinement.

Conclusion

Integrating real-world industrial problems into engineering capstone design courses presents both a valuable opportunity and a complex challenge. This study has demonstrated that while industry-provided problems offer authentic learning experiences, they often require thoughtful refinement to align with academic standards and pedagogical goals. Through iterative collaboration among instructors, students, and industry partners, these problems can be transformed into robust educational tools that foster critical thinking, problem-solving, and professional readiness. The findings underscore the importance of structured guidance, strategic framing, and continuous negotiation to ensure that each project delivers equitable and meaningful outcomes. As engineering education continues to evolve in response to industry demands, future research should explore the long-term impact of these refined

capstone experiences on graduates' transition into the workforce and their capacity to address complex, ill-structured problems in professional settings.

References

- Abdullah, S. (2021). Enhancing industrial engineering education through capstone design integration. *Journal of Engineering Education and Practice*, 10(2), 45–53.
- Badir, A., O'Neill, R., Kinzli, K.-D., Komisar, S., & Kim, J.-Y. (2023). Fostering project-based learning through industry engagement in capstone design projects. *Education Sciences*, 13(4), 361. <https://doi.org/10.3390/educsci13040361>
- Berry, F. C., Huang, W., & Exter, M. (2024). Continuous improvement in an engineering technology capstone sequence. *International Journal of Designs for Learning*, 15(3), 34–44. <https://doi.org/10.14434/ijdl.v15i3.36678>
- Biney, P. (2007). Assessing ABET outcomes using capstone design courses. *American Society for Engineering Education*. <https://peer.asee.org/assessing-abet-outcomes-using-capstone-design-courses.pdf>
- Brackin, P., & Gibson, J. D. (2007). *Capstone design projects with industry: Using rubrics to assess student design reports*. ASEE Annual Conference & Exposition.
- Campilho, R. D. S. G., & Silva, F. J. G. (2023). Industrial process improvement by automation and robotics. *Machines*, 11(11), 1011. <https://doi.org/10.3390/machines11111011>[1]
- Chong, A., & Romkey, L. (2022). *Testing inter-rater reliability in rubrics for large-scale undergraduate independent projects*. CEEA Proceedings.
- Das, T. (2024). Productivity optimization techniques using industrial engineering tools: A review. *International Journal of Science and Research Archive*, 12(1), 375–385. <https://doi.org/10.30574/ijrsra.2024.12.1.0820>[2]
- Garay-Rondero, C. L., et al. (2024). *Competency-based assessment tools for engineering higher education*. *Cogent Education*, 11(1), 2392424. <https://doi.org/10.1080/2331186X.2024.2392424>
- GeeksforGeeks. (2025). *Top data analytics projects*. <https://www.geeksforgeeks.org/data-analysis/data-analyst-projects/>
- Georgia Institute of Technology. (2025). *Senior design capstone projects*. H. Milton Stewart School of Industrial and Systems Engineering. <https://capstone.isye.gatech.edu/>
- Goldberg, G. L. (2014). *Revising an engineering design rubric: A case study*. *Practical Assessment, Research & Evaluation*, 19(8), 1–9.
- International Engineering Alliance. (2013). Graduate attributes and professional competencies (Version 3).
- International Engineering Alliance. (2021). *Graduate Attributes and Professional Competencies*.
- Jonassen, D. H. (2000). *Toward a design theory of problem solving*. *Educational Technology Research and Development*, 48(4), 63–85. <https://doi.org/10.1007/BF02300500>
- Law, A. M., & Kelton, W. D. (2014). *Simulation modeling and analysis*. McGraw-Hill Education.
- Martínez León, H. C. (2019). Bridging theory and practice with Lean Six Sigma capstone design projects. *Quality Assurance in Education: An International Perspective*, 27(1), 41–55. <https://eric.ed.gov/?id=EJ1206349>
- Mat Isa, C. M., et al. (2021). *Effective implementation of complex engineering problems in Malaysian engineering curricular*. *Asian Journal of University Education*, 17(4), 1–15.
- Mittal, A., Adolfsen, D., Matson, M., Hiniker, W., Patterson, G., & Coleman, P. (2020). Community-based capstone projects in industrial engineering. *Proceedings of the IISE Annual Conference*. <https://www.researchgate.net/publication/345460025>
- Mostafapour, M., & Hurst, A. (2020). An exploratory study of teamwork processes and perceived team effectiveness in engineering capstone design teams. *International Journal of Engineering Education*, 36(1B), 436–449. https://www.ijee.ie/1atestissues/Vol36-1B/15_ijee3885.pdf
- National University of Singapore. (2025). *EDIC Project Showcase – Engineering Design and Innovation Centre*. <https://cde.nus.edu.sg/edic/projects/showcase/>
- Purdue University. (2025). *Examples of past projects – Edwardson School of Industrial Engineering*. <https://engineering.purdue.edu/IE/corporatepartners/examples>
- Saha, A. K. (2024). A data-driven industrial engineering approach: Enhancing operational efficiency in manufacturing and service sectors. *Journal of Scientific and Engineering Research*, 11(11), 169–178. <https://jsaer.com/download/vol-11-iss-11-2024/JSAER2024-11-11-169-178.pdf>[3]
- Sanders, M. S., & McCormick, E. J. (1993). *Human factors in engineering and design*. McGraw-Hill Education.

- Schmidt, P. L., & Conrad, J. M. (2012). Capstone 101: A framework for implementation of an ABET-compliant capstone sequence. American Society for Engineering Education. https://webpages.charlotte.edu/~jmconrad/Publications/ASEE2012_Capstone_101_Final.pdf
- Sterman, J. D. (2000). *Business dynamics: Systems thinking and modeling for a complex world*. McGraw-Hill Education.
- Strobel, J., & van Barneveld, A. (2009). When is PBL more effective? A meta-synthesis of meta-analyses comparing PBL to conventional classrooms. *Interdisciplinary Journal of Problem-Based Learning*, 3(1), 44–58. <https://doi.org/10.7771/1541-5015.1046>
- Strobel, J., Wang, J., & Weber, N. R. (2013). Problem typology and transitions in problem-based learning. *Interdisciplinary Journal of Problem-Based Learning*, 7(2), 1–17. <https://doi.org/10.7771/1541-5015.1359>
- University of Oklahoma. (2025). *Writing Center resources and citation guides*. <https://www.ou.edu/writingcenter/resources>
- Watkins, G. (2022). Incorporating new ABET outcomes into a two-semester capstone design course. *Capstone Design Community Proceedings*. http://www.capstonedesigncommunity.org/sites/default/files/proceedings_papers/Watkins_ABETOutcomes_CDC22.pdf
- Womack, J. P., & Jones, D. T. (1996). *Lean thinking: Banish waste and create wealth in your corporation*. Simon & Schuster.
- Woods, D. R. (1983). *Problem solving*. American Institute of Chemical Engineers.

Copyright Statement

Copyright © 2025 Syed Hassan, Syed Ahmad Helmi, Ramsey, Aaron, Zehrung, Craig Allen, Kothari, Prathyush Dinesh, Lumbea, Maxell Pasia, Mohd-Yusof, Khairiyah,: The authors assign to the Research in Engineering Education Network (REEN) and educational non-profit institutions a non-exclusive license to use this document for personal use and in courses of instruction provided that the article is used in full, and this copyright statement is reproduced. The authors also grant a non-exclusive license to REEN to publish this document in full on the World Wide Web (prime sites and mirrors), on portable media, and in printed form within the REES and RCEE & RHED 2025 proceedings. Any other usage is prohibited without the express permission of the authors.