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Advancing Student-Centered Learning in Industrial Engineering: Project Scaffolding as a Pathway to Engagement and Workforce Readiness

John Leonardo Vargas Mesa
Dr. Lisa Bosman, Purdue University (West Lafayette, IN, USA)

Dr. Lisa Bosman, PhD in Industrial Engineering, is an Associate Professor in the Purdue Polytechnic Institute at Purdue University. Her engineering education research interests include entrepreneurially minded learning, interdisciplinary education, and faculty professional development.

Nidhi Kirani, Purdue University – West Lafayette (College of Engineering)
Trisha Bimal Thakkar, Purdue University at West Lafayette (COE)

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Abstract: This Work-in-Progress study examines how project scaffolding influences student learning and engagement in an undergraduate Industrial Engineering optimization course. The semester-long project was divided into structured milestones—proposal, update, and final submission—to support student progress. A thematic review of the reflections revealed four major themes: (1) Methods of Skill Development through consistent practice, independent discovery, and understanding foundational concepts; (2) Navigating Technical Challenges such as cleaning data, debugging code, and designing a graphical user interface; (3) Discovering Real-World Relevance of coding and data analysis in professional and societal contexts; and (4) Collaboration, where students reported benefits like skill development and idea exchange, but also interpersonal challenges. Overall, students reported that scaffolding strengthened their problem-solving skills, technical proficiency, and gave them a clearer sense of how coursework connects to real life applications. The findings suggest that instructors may use structured scaffolding in complex, collaborative projects to treat engineering education as a developmental process, where concepts and technical skills evolve into professional independence.

1. Introduction

Engineering education frequently asks students to demonstrate complex problem-solving, design, and analytical skills through large, end-of-semester projects [1]. From a *reverse engineering* perspective, these final deliverables often assume that students already possess the ability to define problems, select appropriate methods, manage time, and integrate theory with practice. In reality, many students are expected to work backward from a sophisticated outcome without explicit guidance on how experts arrive there. When this structured support is absent, students often experience cognitive overload, uneven team participation, procrastination, and superficial engagement with course concepts [2]. Projects can become exercises in task completion rather than learning, privileging students with prior experience while unintentionally disadvantaging others. As a result, opportunities for iterative learning, feedback, and skill development (particularly in self-regulated learning) are frequently missed [3].

To address these challenges, this study implemented a structured, phased project scaffold approach in an undergraduate industrial engineering optimization course. The intervention was designed to align the learning process more closely with professional engineering practice by breaking a complex, open-ended optimization project into clearly defined stages with explicit expectations and formative feedback [4]. Students were required to articulate a problem and proposed solution approach early in the semester, reflect on progress and refine their methods mid-course, and synthesize their work in a comprehensive final deliverable. This approach emphasized active learning, inclusion, and accountability while supporting students as they developed both technical and professional competencies within the context of real-world optimization problems.

The guiding research question for this work-in-progress study is: *How does integrating scaffolding improve student perceptions of learning and engagement in an undergraduate industrial engineering optimization course?*

The contribution of this study lies in providing empirical evidence that a structured, staged project approach can enhance students' confidence, engagement, and higher-order learning in engineering education. By documenting both the implementation and outcomes of this instructional strategy, this work offers a transferable model for instructors seeking to improve project-based learning experiences while supporting diverse student populations.

2. Background

Scaffolding is an instructional strategy grounded in constructivist learning theory that emphasizes providing structured support as learners engage in complex tasks, gradually reducing that support as competence and confidence increase [5]. In engineering education, scaffolded assignments often decompose large, open-ended problems into sequenced activities such as problem definition, preliminary analysis, iteration, and final synthesis. Completing these structured phases mirrors professional engineering practice, where projects evolve through proposals, reviews, revisions, and final deliverables rather than appearing fully formed [6]. As students repeatedly engage in this process, they develop transferable workplace skills including project planning, iterative problem-solving, communication with stakeholders, and responsiveness to feedback. These experiences help bridge the gap between academic learning and professional expectations by making expert thinking processes explicit and repeatable [7].

From a Universal Design for Learning (UDL) perspective, scaffolded learning offers substantial benefits by promoting multiple means of engagement, representation, and action or expression [8]. Structured milestones reduce cognitive overload by clarifying expectations and timelines, allowing students to focus on learning rather than task ambiguity [2]. Scaffolding also supports learner variability by providing early feedback, flexible pathways for improvement, and opportunities for reflection, which are particularly beneficial for students with diverse academic backgrounds, learning preferences, or levels of prior experience [9]. By normalizing iteration and revision, scaffolded approaches foster a growth-oriented learning environment that increases motivation, persistence, and a sense of belonging. In engineering contexts, this inclusivity is especially important for supporting underrepresented students who may otherwise be disproportionately affected by high-stakes, unstructured assessments.

Despite its advantages, implementing scaffolding in open-ended assignments presents several challenges [7]. Designing effective scaffolded tasks requires careful alignment with learning objectives to ensure that intermediate steps meaningfully contribute to the final outcome rather than becoming disconnected or overly prescriptive. Instructors may face increased workload due to the need for frequent feedback, rubric development, and coordination of milestones [10]. There is also a risk of over-structuring, which can limit creativity, reduce student autonomy, or lead learners to view projects as a checklist rather than an authentic problem-solving experience [11]. Balancing structure with flexibility is particularly difficult in open-ended engineering projects, where ambiguity is an essential feature of real-world problems. As a result, successful implementation of scaffolding requires thoughtful design, intentional fading of support, and institutional support to sustain instructional effort.

3. Methods

3.1 Intervention

Project scaffolding is a framework that supports students in completing complex projects by dividing them into smaller, more manageable phases. Students in an undergraduate optimization course completed a semester-long Final Optimization Project in three major scaffolds: (1) Project proposal, (2) Project update, and (3) Final project submission. The objective of the project was to apply optimization techniques to a problem, formulate and implement an appropriate mathematical model, and analyze its performance to propose practical solutions.

In the **first** scaffold (Project Proposal), students submitted a two-page document that detailed the problem contexts, methods of data collection, proposed methodology, and supporting literature. The **second scaffold (Project Update)** required a 5-10 minute video that summarized the problem, explained the mathematical model, and demonstrated the group's progress in software implementation using tools such as Python or MATLAB. The **third scaffold (Final Report)** involved producing a 5-7 page report including qualification, authors, abstract, introduction, methodology , results, analysis, conclusions, and references. Each stage was evaluated by both the instructor and peers based on technical quality and clarity of explanations, as well as overall quality. The project scaffolding intervention aimed to reinforce student learning and problem-solving skills throughout the project design and development process. Data was collected at the end through an open-ended student survey to assess the intervention's effect on perceptions of learning and engagement.

3.2 Participants

The participants included undergraduate students enrolled in the industrial engineering course. The selected course is a program core requirement that introduces students to optimization techniques with an emphasis on formulation, analysis, and solution of optimization problems. Students learn to model engineering systems, explore linear and nonlinear programs, and use computational tools. The course is rigorous and bridges advanced mathematics, algorithmic thinking, and engineering applications, allowing students to apply their knowledge to industrial engineering contexts. The approximate class size was 24, and 20 of those students provided responses in the survey that was used for data collection.

3.3 Data Collection Instrument

Qualitative data were collected from an open-ended student survey with the following questions. Each question asked the students for a minimum of 150 words in their response.

1. What part of the final project did you find most challenging and why?
2. What part of the final project did you feel you could contribute the most value and why?
3. What advice might you have for new students enrolled in this course?
4. This is the end of the assessment. Is there anything else you'd like to share?

3.4 Data Analysis Procedure

The study used a qualitative coding framework with thematic analysis. Qualitative thematic analysis is a technique used in research to process and understand data by identifying key words or patterns in the text. There are six steps in the analysis process [12]: finding key quotes, coding for patterns, creating themes, interpretation of themes, and development of a conceptual model. Two researchers read through the translated data and used NVivo 15 software to code the responses. Four themes and 12 subthemes were produced, and one of the researchers wrote a report to explain the themes and provide quoted evidence for each theme.

4. Preliminary Results

Figure 1 provides a visual summary of the preliminary results, which highlights the themes and subthemes.

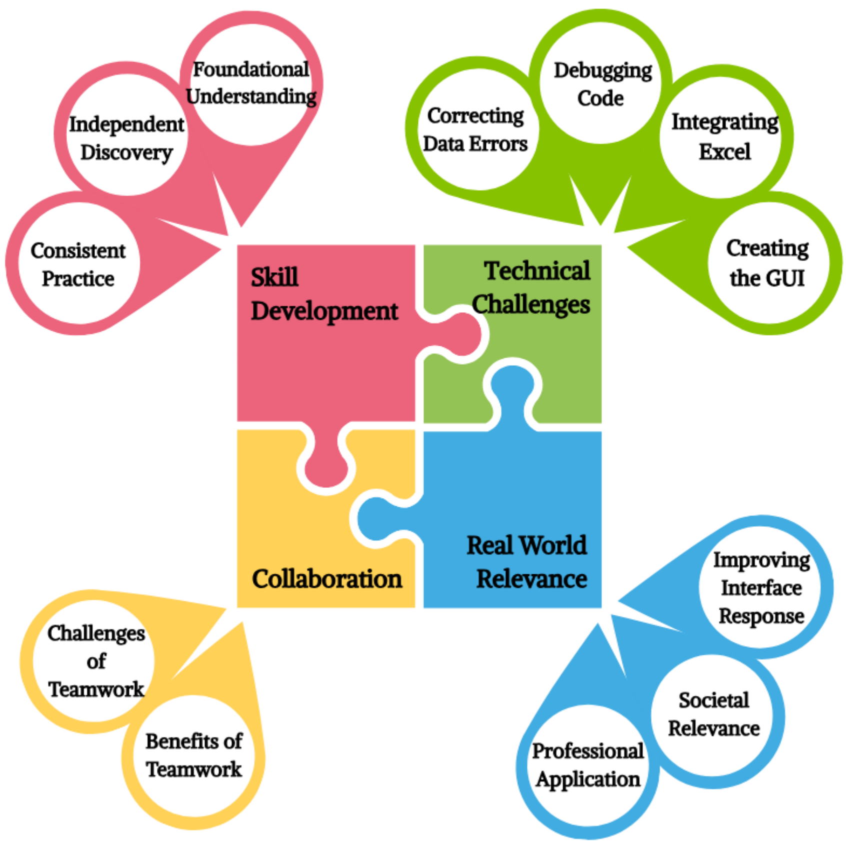

Figure 1. Visual Summary of Themes

5. Conclusion

This work-in-progress study suggests that integrating scaffolded project milestones in an undergraduate industrial engineering optimization course positively influenced student perceptions of learning and engagement by reducing ambiguity, promoting iterative learning, and supporting skill development through practice, independent discovery, and mastery of foundational concepts. The findings indicate that instructors, curriculum designers, and departments may improve project-based learning by adopting structured, feedback-oriented scaffolding that emphasizes learning progression and workforce-relevant skills, while encouraging students to approach complex projects as developmental experiences grounded in planning, iteration, and conceptual understanding.

6. References

[1] P. Guo, N. Saab, L. S. Post, and W. Admiraal, "A review of project-based learning in higher education: Student outcomes and measures," *International journal of educational research,* vol. 102, p. 101586, 2020.

[2] S. Koudsia and M. Kirchner, "Reducing cognitive overload for students in higher education: A course design case study," *Journal of Higher Education Theory and Practice,* vol. 24, no. 10, pp. 97-124, 2024.

[3] J. Zheng, W. Xing, G. Zhu, G. Chen, H. Zhao, and C. Xie, "Profiling self-regulation behaviors in STEM learning of engineering design," *Computers & Education,* vol. 143, p. 103669, 2020.

[4] B. Jones, "Good practice: Scaffolded, collaborative project-based learning," *Journal of the European Honors Council,* vol. 3, no. 1, pp. 1-16, 2019.

[5] N. R. Mishra, "Constructivist approach to learning: An analysis of pedagogical models of social constructivist learning theory," *Journal of research and development,* vol. 6, no. 01, pp. 22-29, 2023.

[6] M. Kaushik, P. Baligar, and G. Joshi, "Formulating an engineering design problem: A structured approach," *Journal of Engineering Education Transformations,* 2018.

[7] B. R. Belland, E. Lee, A. Y. Zhang, and C. Kim, "Characterizing the most effective scaffolding approaches in engineering and technology education: A clustering approach," *Computer Applications in Engineering Education,* vol. 30, no. 6, pp. 1795-1812, 2022.

[8] Q. I. Almeqdad, A. M. Alodat, M. F. Alquraan, M. A. Mohaidat, and A. K. Al-Makhzoomy, "The effectiveness of universal design for learning: A systematic review of the literature and meta-analysis," *Cogent Education,* vol. 10, no. 1, p. 2218191, 2023.

[9] B. Frank, N. Simper, and J. Kaupp, "Formative feedback and scaffolding for developing complex problem solving and modelling outcomes," *European Journal of Engineering Education,* vol. 43, no. 4, pp. 552-568, 2018.

[10] J. Stevens, "Finding the balance: Creating meaningful assignments without overwhelming instructional workload," *Journal of Educators Online,* vol. 15, no. 3, p. n3, 2018.

[11] J. Chen, A. Kolmos, and X. Du, "Forms of implementation and challenges of PBL in engineering education: a review of literature," *European Journal of Engineering Education,* vol. 46, no. 1, pp. 90-115, 2021.

[12] M. Naeem, W. Ozuem, K. Howell, and S. Ranfagni, "A Step-by-Step Process of Thematic Analysis to Develop a Conceptual Model in Qualitative Research," *International Journal of Qualitative Methods,* vol. 22, p. 16094069231205789, 2023, doi: 10.1177/16094069231205789.