Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
Paper ID #49143

Fostering Adaptive Expertise in First-Year Engineering Design: Coaching, Iterative Prototyping, and Structured Learning

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Abstract

This *evidence-based practice* paper investigates the development of adaptive expertise in first-year engineering students within a “Design for Manufacturing” course. Adaptive expertise, the ability to apply technical knowledge creatively and flexibly to unfamiliar challenges, is increasingly essential for addressing complex, real-world engineering problems. This study focuses on how structured coaching and iterative prototyping facilitate the cultivation of adaptive expertise, aligning with Kolb’s Experiential Learning Cycle and key ABET outcomes. Motivation: First-year engineering courses are pivotal in equipping students with foundational technical skills and problem-solving abilities. However, traditional engineering education often emphasizes routine expertise, prioritizing efficiency over creativity and adaptability. By integrating structured coaching with hands-on prototyping activities, the "Design for Manufacturing" course seeks to foster adaptive expertise, preparing students to tackle open-ended problems with confidence and ingenuity. This study aims to provide evidence-based insights into the effectiveness of this pedagogical approach, contributing to broader efforts in enhancing first-year engineering education.

Background: Adaptive expertise, as differentiated from routine expertise, requires a balance of efficiency and innovation [1]. Kolb’s Experiential Learning Cycle [2] offers a valuable framework for fostering this adaptability through iterative processes, emphasizing Concrete Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation. Prototyping, progressing through conceptual, functional, and production stages, provides a practical mechanism for engaging students in iterative design. Prior studies, such as Larson et al. [3], have demonstrated the potential of project-based learning to develop adaptive expertise in upper-division courses, but limited evidence exists for first-year contexts.

Methods/Assessment: The study takes place in a first-year “Design for Manufacturing” course that emphasizes hands-on learning. Students work in teams to identify design problems, develop concepts, and fabricate prototypes using tools such as 3D printers, CNC/manual mills, and welding equipment. A taxonomy of prototypes guides the process:

1. Conceptual Prototypes: Low-fidelity models (e.g., cardboard) for exploring ideas.
2. Functional Prototypes: Medium-fidelity models incorporating core design elements for testing and refinement.
3. Production Prototypes: High-fidelity models focusing on manufacturability and precision.

The instructional approach includes structured milestones developed by near-peer mentors. These milestones guide students through key stages: problem definition, concept sketching, material selection, iterative prototyping, and final production. Coaching interventions are tailored to each phase, emphasizing creativity in early stages and technical refinement later.

Data collection involves case studies of student projects, including a butterfly knife, a pinball machine, and a lightsaber. Documentation includes student reflections, coaching interactions, and prototype evaluations. Thematic analysis [4] maps outcomes to Kolb's learning cycle and adaptive expertise dimensions.

Results: Preliminary findings highlight the effectiveness of structured coaching and iterative prototyping in fostering adaptive expertise. Successful projects demonstrated:

- Creativity and Problem-Solving: Teams iterated through multiple conceptual and functional prototypes, refining designs based on performance data and user feedback.
- Adaptability: Students navigated uncertainties in manufacturability and design specifications, showcasing flexibility in their approaches.
- Alignment with Theoretical Frameworks: Evidence supports the integration of Kolb's Experiential Learning Cycle, with students moving fluidly through its phases during the prototyping process.

For example, the butterfly knife project evolved from sketches and 3D-printed models to CNC-machined production prototypes. Iterative testing revealed design flaws, which were addressed through collaborative problem-solving. In contrast, teams that struggled often skipped early prototyping stages or underestimated manufacturability, requiring additional coaching to revisit fundamental design principles.

These findings suggest that coaching and structured milestones are instrumental in developing the skills and mindsets necessary for real-world engineering challenges. The study contributes practical insights into the design of first-year engineering courses, with implications for broader adoption of adaptive expertise frameworks across educational contexts.

Keywords: Adaptive Expertise, Iterative Prototyping, First-Year Engineering, Design Coaching, Experiential Learning

1. Introduction

First-year engineering courses are a critical entry point for students, shaping their foundational skills and introducing them to the challenges and opportunities within the field. These courses are often designed to develop technical competencies, such as machining, drafting, and basic design principles. However, the rapidly evolving nature of engineering demands more than technical expertise. To navigate complex, real-world problems, engineers must also cultivate adaptive expertise, a blend of creativity, flexibility, and problem-solving ability that enables them to apply knowledge to new and unforeseen challenges.

Despite this need, traditional engineering education frequently focuses on developing routine expertise. This approach, while effective in producing technically proficient engineers, often emphasizes efficiency over innovation, leaving students unprepared for the uncertainty and ambiguity inherent in many engineering problems. This gap in educational focus can result in graduates who struggle to adapt to new technologies, diverse work environments, and the dynamic demands of their profession.

The motivation for this study arises from the recognition that first-year engineering students represent an ideal population for fostering adaptive expertise. Early exposure to problem-solving under uncertainty, guided by structured coaching and iterative design, can lay the groundwork for lifelong learning and innovation. By integrating hands-on, project-based learning with coaching tailored to different stages of the design process, the "Design for Manufacturing" course aims to address this gap. The course employs iterative prototyping and scaffolded milestones to guide students through progressively complex challenges, encouraging them to think critically, reflect on their learning, and adapt their approaches.

This motivation is further reinforced by the broader goals of engineering education, such as those outlined in *The Engineer of 2020* report by the National Academy of Engineering [5]. The report emphasizes the need for future engineers to be agile learners capable of mastering emerging technologies and solving interdisciplinary problems. Developing adaptive expertise aligns directly with this vision, equipping students with not only the technical skills but also the mindset necessary to thrive in an ever-changing professional landscape.

By exploring how structured coaching and iterative prototyping can foster adaptive expertise in first-year engineering students, this study seeks to demonstrate a practical and scalable approach to addressing these challenges. The findings aim to inform best practices in first year engineering education, contributing to the ongoing evolution of curricula that prepare students for both academic success and the complexities of modern engineering practice.

2. Background

The concept of adaptive expertise is foundational to the development of engineers capable of addressing the unpredictable challenges of a rapidly evolving world. Unlike routine expertise, which emphasizes efficiency and proficiency in established tasks, adaptive expertise blends creativity, flexibility, and the ability to apply knowledge to novel problems. Hatan and Inagaki [1] describe adaptive experts as those who extend beyond mastery of existing skills to innovate and tackle new challenges. This ability is particularly important in engineering, where technological advancements and global issues often require solutions that go beyond conventional approaches.

Kolb's Experiential Learning Cycle [2] provides a theoretical framework for fostering adaptive expertise. The cycle describes learning as a dynamic process involving four interconnected stages: Concrete Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation. This iterative model supports the development of problem-solving skills by encouraging students to engage in hands-on activities, reflect on outcomes, conceptualize improvements, and test new approaches. Integrating this cycle into engineering education allows students to experience and learn from the uncertainty and iteration inherent in real-world design challenges.

Prototyping is another critical component in the development of adaptive expertise. Cross [6] highlights the role of prototyping in stimulating creativity and improving design through iteration. By engaging with conceptual prototypes (low-fidelity models used to explore initial ideas), functional prototypes (medium-fidelity models for testing and refinement), and production prototypes (high-fidelity models focusing on manufacturability), students can navigate the complexities of design processes. Each stage serves a distinct educational purpose, from fostering creativity to emphasizing technical precision and manufacturability.
Structured coaching has emerged as a vital tool in facilitating these processes. Neeley's work on adaptive design expertise [7] emphasizes the importance of tailored guidance in helping students develop the capacity to adapt their knowledge to new contexts. Coaches can provide critical support at key milestones, helping students understand when and how to use different types of prototypes effectively. This structured approach enables students to build confidence, refine their skills, and develop the flexibility necessary for adaptive expertise.

The need for adaptive expertise is further underscored by the evolving goals of engineering education. The *Engineer of 2020* report by the National Academy of Engineering [5] envisions future engineers as agile learners who can quickly adapt to emerging technologies and new problem domains. Similarly, ABET criteria [8] emphasize outcomes such as life-long learning and the ability to address open-ended problems in interdisciplinary contexts. These objectives align with the principles of adaptive expertise, highlighting the importance of educational strategies that prepare students for dynamic professional environments.

Despite its importance, adaptive expertise is often underemphasized in first-year engineering courses. Traditional curricula frequently focus on routine skills, such as machining or drafting, with limited opportunities for students to engage in open-ended, iterative design processes. This paper seeks to address this gap by demonstrating how the integration of Kolb's Experiential Learning Cycle, iterative prototyping, and structured coaching can foster adaptive expertise in first-year students. By building on prior research, such as Larson et al.'s [3] work on adaptive expertise in upper-division courses, this study aims to extend these practices to the critical first-year experience, providing evidence for their broader applicability in engineering education.

Structured coaching, informed by Neeley's theory of adaptive design expertise [7], plays a central role in the course. Early coaching sessions focus on fostering creativity and encouraging exploration of diverse design ideas. As projects progress, the focus shifts to developing technical precision, ensuring tool safety, and addressing manufacturability challenges. This adaptive coaching framework helps students balance creativity and efficiency, guiding them toward innovative and technically sound solutions.

In addition to analyzing specific projects, the study explores broader implications for integrating adaptive expertise frameworks into first-year engineering curricula. It builds on prior research, such as Larson et al.'s [3] findings on project-based learning in upper-division courses, demonstrating the relevance of these principles for early engineering education.
By adopting a multi-faceted approach, the study offers a comprehensive understanding of how first-year students can develop the creativity, flexibility, and problem-solving skills necessary for success in dynamic engineering environments. This research aims to inform best practices in

engineering education, providing a scalable model for fostering adaptive expertise at all levels of the curriculum.

3. Methods

Research Design and Methods

This study adopts a qualitative case study approach to investigate how structured coaching and iterative prototyping foster adaptive expertise among first-year engineering students. The research is embedded within a "Design for Manufacturing" course that emphasizes hands-on, project-based learning. The course framework combines scaffolded milestones with a taxonomy of prototypes to guide students through the iterative design process. Students engage in tasks ranging from problem identification and conceptual sketching to functional prototyping and the fabrication of production-grade models.

The prototyping taxonomy, inspired by Cross [6], categorizes student work into three stages: conceptual prototypes (low-fidelity models like sketches or cardboard for exploring initial ideas), functional prototypes (medium-fidelity models tested and refined using machine tools), and production prototypes (high-fidelity models focusing on manufacturability and design specifications). This structured progression aligns with Kolb's Experiential Learning Cycle [2], encouraging students to reflect on their designs and adapt based on iterative feedback.
Data collection focuses on student projects, including artifacts such as design documentation, iterative prototypes, and written reflections. Observations of coaching interactions and team dynamics provide additional insight into how students adapt their approaches over time. Thematic analysis, following Attride-Stirling's methodology [4], is used to identify patterns in student learning and adaptation, mapping these to stages in Kolb's cycle.

Participant Population and Context

The study population consists of first-year engineering students enrolled in the "Design for Manufacturing" course in the Leslie A. Rose Department of Mechanical Engineering at South Dakota School of Mines & Technology. Students work in small teams to complete semester-long projects, designing and fabricating functional prototypes. Examples of student projects include a butterfly knife, a pinball machine, and a lightsaber. These projects require the integration of technical skills with creative problem-solving, making them ideal for studying the development of adaptive expertise.

The course is structured around scaffolded milestones developed by near-peer mentors, advanced undergraduate students with prior experience in engineering design. These milestones include key phases such as problem definition, material selection, iterative prototyping, and final production. The near-peer mentors provide tailored coaching at each stage, facilitating student learning and encouraging reflection on the design process.

Research Questions

1. How does structured coaching impact the development of adaptive expertise in first-year engineering students?
2. In what ways do iterative prototyping practices contribute to students' ability to navigate uncertainty and adapt their designs?
3. How do students engage with the stages of Kolb's Experiential Learning Cycle during the prototyping process?

4. Results

Observation of Design Processes Led by Peer Coaches: A Semester Roadmap

The "Design for Manufacturing" course unfolds over a 10–12-week semester, providing first-year engineering students with a structured yet dynamic environment to develop both technical skills and adaptive expertise. Peer coaches, acting as mentors and guides, play a pivotal role in steering students through the design and manufacturing process. The course is structured around scaffolded milestones, designed to align with the iterative nature of prototyping and to foster creativity, adaptability, and problem-solving.

Weeks 1–2: Building the Foundation

In the initial weeks, the emphasis is on establishing the foundation for the design process. Students engage in machine shop training, learning the safe and effective use of tools such as 3D printers, CNC/manual mills, and welding equipment. During this phase, students collaborate in teams to define their design problems and conceptualize initial solutions. They use software like Autodesk Inventor or SolidWorks to create detailed design drawings, which form the basis for their projects.

For instance, the butterfly knife team began by brainstorming ergonomic and aesthetic considerations, producing sketches and 3D-printed prototypes to explore early design concepts. Peer coaches guided students in critically evaluating their ideas, ensuring they remained open to revisions while maintaining focus on manufacturability.

Weeks 3–4: Advanced Prototyping and Manufacturing

By the third week, teams transition from conceptual models to functional prototyping. Functional prototypes [6] enable teams to test and refine key design elements. Students begin material selection and start working with machine tools under the guidance of peer coaches. Roles are assigned within each team to streamline operations, with some members focusing on CAD updates while others engage directly in machining.

The butterfly knife team, for example, advanced to CNC machining aluminum components, iteratively refining blade tolerances to improve alignment and usability. Peer coaches provided targeted support during these sessions, offering feedback on tool usage and encouraging reflection after each iteration.

Weeks 5–6: Finalization and Reflection

The latter half of the semester focuses on transitioning functional prototypes into production prototypes. Students fabricate high-fidelity models using final materials, emphasizing manufacturability and precision. Assembly, testing, and optimization occur during this phase, culminating in prototypes that meet both technical specifications and user requirements.
For the butterfly knife team, this stage included anodizing components for durability and aesthetics. Teams also prepared detailed documentation, reflecting on the design and manufacturing process. Peer coaches facilitated these reflections, helping students connect their learning to broader engineering principles.

Iterative Prototyping as a Learning Tool

At the heart of the course is the iterative nature of prototyping, which fosters adaptive expertise by encouraging students to treat each version of their prototype as a learning opportunity. Conceptual prototypes spark creativity and help students explore broad ideas without the constraints of high fidelity. Functional prototypes enable teams to test and refine their designs, identifying flaws that can be corrected in subsequent iterations. Production prototypes focus on manufacturability, requiring students to balance precision with practicality.

The pinball machine and lightsaber projects further illustrate the value of this approach. The pinball machine team integrated mechanical and electrical systems, using functional prototypes to troubleshoot inconsistencies in flipper performance. Similarly, the lightsaber team refined their handle design to address heat dissipation issues in the LED system, combining aesthetic goals with technical requirements.

Role of Peer Coaches

Throughout the semester, peer coaches adapt their guidance to align with the specific needs of students at each stage of the design process. Early coaching sessions prioritize creativity, helping students navigate ambiguity and explore multiple ideas. As the projects progress, coaches shift their focus to technical precision, ensuring students understand safety protocols and manufacturability considerations. This adaptive coaching model mirrors real-world engineering workflows, preparing students to manage uncertainty and refine their problem-solving skills.

Reflection on Adaptive Expertise Development

The iterative design process, combined with structured coaching, provides a rich environment for cultivating adaptive expertise. Students learn to apply their knowledge creatively and flexibly to evolving challenges, a skill highlighted by Hatan and Inagaki [1]. Teams that embrace this iterative approach demonstrate enhanced problem-solving capabilities, greater resilience in the face of setbacks, and an improved ability to manage uncertainty. Conversely, teams that bypass early prototyping stages or fail to reflect on their designs often encounter significant challenges later in the process. Peer coaches play a crucial role in addressing these gaps, helping students revisit foundational principles and adjust their approaches.

The “Design for Manufacturing” course offers a model for modern engineering education, blending technical rigor with creativity and adaptability. By emphasizing iterative prototyping, targeted coaching, and structured milestones, the course prepares students to tackle real-world engineering challenges with confidence and ingenuity. Projects such as the butterfly knife, pinball machine, and lightsaber exemplify the transformative potential of this approach, showcasing how first-year students can become capable, innovative engineers through hands-on learning and reflective practice.

Figure 1. Team Butterfly Knife manually milling components in preparation of CNC milling the blades and handles of the knife.

Figure 2. Team Lightsaber presenting their final and completed model at the design fair during week 6.

Figure 3. Team Pinball in between weeks 4-5, wiring the solenoid’s that control the flappers.

Figure 4. Team Pinball cutting the wood paneling used to hide components during week 5.

5. Findings

The findings of this study illustrate how structured coaching, scaffolded milestones, and iterative prototyping collectively foster adaptive expertise in first-year engineering students. By analyzing student projects and their progression through conceptual, functional, and production prototyping stages, clear patterns of learning, adaptability, and problem-solving emerged.

In the butterfly knife project, the team began by creating detailed design drawings using Autodesk Inventor and 3D-printed a conceptual prototype to evaluate the overall form and mechanism. This initial phase allowed the team to explore creative ideas and address potential ergonomic challenges. Through structured coaching, students transitioned to functional prototypes, using CNC milling and manual machining to refine their designs. Iterative testing revealed alignment issues in the knife's hinges, prompting the team to adjust tolerances and explore alternative materials. In the final production stage, the team anodized aluminum components for durability and aesthetic appeal, resulting in a polished, functional prototype. This iterative process highlighted the role of reflection and experimentation, consistent with Kolb's [2], as students navigated the complexities of manufacturability and precision.

The pinball machine project exemplified the integration of mechanical and electrical systems, showcasing the interplay between creativity and technical skill. Initially, the team developed conceptual sketches and constructed low-fidelity models to map the layout of the machine's components. Functional prototyping involved incorporating electronic components and testing the mechanical functionality of the launcher and flippers. When testing revealed inconsistent power delivery to the flippers, coaching sessions focused on troubleshooting electrical connections and optimizing power distribution. By the production stage, the team had resolved these issues and created a high-fidelity prototype that balanced mechanical reliability with visual appeal. This progression underscored the importance of iterative prototyping in addressing unforeseen challenges, fostering both technical proficiency and adaptability.

In the lightsaber project, students combined advanced manufacturing techniques with creative design elements. Starting with conceptual prototypes, they used cardboard and foam to explore the design's form and handle ergonomics. Functional prototypes incorporated LED lighting systems and structural components machined from aluminum. During iterative testing, the team discovered issues with heat dissipation in the LED system, requiring modifications to the handle's ventilation design. Through structured coaching, students developed a final production prototype that not only addressed technical challenges but also aligned with aesthetic goals. This project highlighted how iterative testing can uncover and resolve complex design issues, promoting both creativity and resilience.

Across these case studies, the observations demonstrated consistent patterns in how students developed adaptive expertise. Successful projects embraced iterative prototyping, using functional prototypes to uncover design flaws and improve manufacturability. Students who reflected on feedback and testing outcomes exhibited greater adaptability, revisiting design choices and refining their solutions based on performance data. These behaviors align with the principles of adaptive expertise as described by Hatan and Inagaki [1] and support the integration of experiential learning frameworks such as Kolb's model [2].

Structured coaching emerged as a critical factor in facilitating these outcomes. Early coaching sessions encouraged students to explore multiple design ideas, fostering creativity and innovation. As projects advanced, coaching shifted to emphasize technical skills, safety protocols, and manufacturability. For example, teams that struggled with early design stages often benefited from interventions that revisited problem definitions and prototyping principles, helping them overcome challenges and achieve successful outcomes.

These results also reinforce the findings of Larson et al. [3], demonstrating the value of adaptive expertise in upper-division project-based courses. By extending these principles to first-year students, this study highlights the potential of structured coaching and iterative prototyping to prepare students for the complexities of real-world engineering challenges from the outset of their academic careers. The combination of hands-on learning, reflection, and iterative improvement equips students with the creativity, flexibility, and problem-solving skills needed to thrive in dynamic professional environments.

6. Discussion

The findings of this study illustrate the transformative role of structured coaching and iterative prototyping in fostering adaptive expertise among first-year engineering students. These educational strategies, embedded within the "Design for Manufacturing" course, demonstrate how first-year experiences can effectively integrate technical and adaptive skill development, aligning with broader goals in engineering education, such as those outlined in the *Engineer of 2020* report by the National Academy of Engineering [5]. This discussion contextualizes these findings within theoretical frameworks, highlights the pedagogical implications, and explores the challenges and opportunities for broader implementation.

One of the central contributions of this study is its alignment with Kolb's Experiential Learning Cycle [2]. The iterative nature of the prototyping process directly maps to Kolb's stages of learning: students engage in Concrete Experience through hands-on fabrication, Reflective Observation by evaluating the performance of their prototypes, Abstract Conceptualization by refining their designs based on observations, and Active Experimentation as they test and implement improvements. These cycles enable students to develop a deeper understanding of the design process and cultivate the flexibility needed to adapt their knowledge to evolving challenges. By structuring the course around these iterative cycles, students not only gain technical skills but also develop the cognitive agility essential for adaptive expertise.

The taxonomy of prototypes used in the course further supports this iterative learning. Drawing on Cross's [6] work, the progression from conceptual to functional to production prototypes allows students to experience design as a dynamic and evolving process. Conceptual prototypes foster creativity and the exploration of broad design ideas, functional prototypes emphasize testing and refinement, and production prototypes instill an appreciation for manufacturability and precision. This staged approach mirrors the dual dimensions of efficiency and innovation that characterize adaptive expertise [1], and prepares students to navigate the uncertainties inherent in real-world engineering problems.

Structured coaching plays a pivotal role in facilitating this progression. Consistent with Neeley's framework for adaptive design expertise [7], coaching interventions are tailored to the specific needs of students at different stages of the design process. Early coaching sessions encourage students to think creatively and explore multiple solutions, while later sessions emphasize technical skills, safety protocols, and the practicalities of fabrication. This targeted guidance helps students balance the demands of innovation and efficiency, allowing them to approach complex design challenges with confidence and adaptability. Moreover, the use of near-peer mentors as coaches creates an environment of relatability and support, enabling students to navigate the learning process with greater ease.

The study's findings also resonate with prior research, such as Larson et al. [3], which highlighted the effectiveness of project-based learning in cultivating adaptive expertise in upper-division courses. Extending these principles to first-year students demonstrate the feasibility and value of introducing adaptive expertise frameworks early in the engineering curriculum. By doing so, students begin to internalize the iterative, reflective, and adaptive processes that will be critical throughout their academic and professional careers.

However, the implementation of these strategies is not without challenges. Some teams struggled with early prototyping stages, often rushing through conceptual design or overlooking manufacturability considerations. These difficulties highlight the importance of reinforcing foundational design principles and encouraging reflection throughout the process. Structured coaching interventions proved effective in addressing these challenges, but they also underscore the need for careful planning and consistent support in scaling this approach to other courses and institutions.

The broader implications of this study extend beyond first-year engineering education. The integration of iterative prototyping and structured coaching provides a replicable model for fostering adaptive expertise in diverse educational contexts. This model aligns with ABET criteria, particularly the emphasis on life-long learning and addressing complex, open-ended problems. Additionally, the study contributes to the growing body of evidence supporting the use of experiential and project-based learning to bridge the gap between traditional technical education and the dynamic demands of modern engineering practice.

The findings of this study highlight the value of structured coaching and iterative prototyping as tools for fostering adaptive expertise in first-year engineering students. By aligning with established theoretical frameworks and addressing practical challenges, this approach provides a robust foundation for developing the creativity, flexibility, and problem-solving skills needed for success in engineering. Future work should explore the scalability of this model to other educational levels and contexts, as well as the potential for integrating digital tools to enhance accessibility and support hybrid or remote learning environments. Through these efforts, engineering education can continue to evolve, equipping students to thrive in a rapidly changing world.

7. Conclusions

This study demonstrates the critical role of structured coaching and iterative prototyping in fostering adaptive expertise among first-year engineering students. By integrating scaffolded milestones and a taxonomy of prototypes within a "Design for Manufacturing" course, the study shows how students can develop both the technical skills and the adaptability necessary for tackling complex, real-world engineering challenges. The iterative approach, rooted in Kolb's Experiential Learning Cycle, enables students to actively engage with design problems, reflect on their progress, and adapt their solutions based on continuous feedback and testing.
The results reveal that students who embrace the iterative prototyping process not only enhance their technical capabilities but also build the cognitive flexibility to address uncertainty and ambiguity, key attributes of adaptive expertise. The structured coaching framework is central to this process, providing targeted guidance that evolves as students progress through the prototyping stages. By balancing creativity, technical precision, and manufacturability, students develop a holistic understanding of the engineering design process and learn to navigate the complexities of open-ended problem-solving.

This work contributes to the growing body of evidence supporting experiential and project-based learning in engineering education. It aligns with the goals of ABET and the *Engineer of 2020* vision by preparing students to adapt to new technologies and emerging challenges in their professional careers. This highlights the potential of extending adaptive expertise frameworks to first-year students, creating a strong foundation for lifelong learning and innovation.

Despite its success, the study also identifies challenges in implementing these approaches, particularly for students who struggle with early design stages or overlook key principles of manufacturability. Addressing these challenges through consistent coaching and reinforcement of design fundamentals is essential for maximizing the impact of this pedagogical model. Future work should explore how these strategies can be scaled to other educational contexts and levels, as well as how digital tools can enhance the accessibility and flexibility of the approach.
In summary, this study provides a practical and evidence-based model for developing adaptive expertise in first-year engineering students. By emphasizing iterative learning, reflection, and structured support, this approach equips students with the skills and mindset to excel in the dynamic and evolving landscape of modern engineering. Through further refinement and dissemination of these practices, engineering education can continue to prepare students not only for the challenges of today but for the uncertainties of the future.

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