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Interactive Design-to-Print Learning in Additive Manufacturing: Integrating Peer Teaching, Micro-Presentations, and Laboratory Practice

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Abstract

Additive manufacturing (AM) education requires instructional approaches that support not only technical knowledge but also communication, teamwork, and design-for-manufacturing skills. This paper presents an interactive teaching framework implemented in a junior–senior level AM course that integrates small-group discussion, student micro-presentations, and iterative design-to-print laboratory cycles. The novelty of the approach lies in the intentional coupling of peer teaching and rapid concept exploration with immediate application through fabrication, followed by structured reflection on design decisions, process constraints, and outcomes.

In this model, students work in teams to research focused AM topics, deliver short presentations, and directly apply concepts in laboratory activities that require design, slicing, manufacturing, and evaluation of printed parts. Each cycle reinforces connections between theory and practice, emphasizing process–property–cost tradeoffs.

Student perceptions were evaluated through an end-of-course survey (n =26). The proposed framework offers a structured and transferable model for integrating active learning with fabrication-based instruction in additive manufacturing, with 88.5% of students reporting increased engagement, 84.6% reporting improved understanding of AM topics, and 73.1% expressing preference for the interactive approach over traditional lectures. Open-ended responses further highlight the value of peer explanation, hands-on fabrication, and iterative reflection in supporting learning.

Findings are based on self-reported survey data, and results reflect perceived benefits rather than direct measures of learning outcomes. These findings are based on self-reported survey data and reflect perceived benefits rather than direct measures of learning outcomes.

1. Introduction

Additive manufacturing has fundamentally changed how engineers approach product design, manufacturing, and production planning. Unlike conventional manufacturing processes, additive manufacturing requires designers to account for process-specific constraints, anisotropic material behavior, build orientation, support strategies, and cost trade-offs at early stages of the design process. As a result, engineers must develop not only strong analytical skills but also the ability to integrate design, materials, and manufacturing considerations within complex and evolving technological contexts. At the same time, modern society demands engineers who can meet diverse societal needs while minimizing cost and efficiently utilizing resources, placing increased emphasis on adaptable, practice-ready engineering graduates (Bai and Singh, 2025).

Meeting these demands requires engineering education to move beyond a primary focus on theoretical content and to incorporate learning experiences that promote problem solving, collaboration, and real-world application. However, traditional lecture-based instruction continues to dominate many engineering curricula, often providing limited opportunities for students to actively engage with course material or apply concepts in authentic contexts. Extensive research in engineering education has demonstrated that active and collaborative learning strategies lead to higher student engagement and improved learning outcomes compared to passive instructional methods (Prince, 2004; Freeman et al., 2014). More recent studies further suggest that project-based and experiential learning approaches enhance students' ability to integrate knowledge, develop professional skills, and prepare for engineering practice (Ramanathan et al., 2025).

These findings are particularly relevant to additive manufacturing education, which is inherently interdisciplinary and application driven. Effective instruction in this area must support students in developing design-for-additive-manufacturing competencies, understanding process–property relationships, and evaluating performance and cost trade-offs. Active learning environments, including structured group work and experiential activities, have also been shown to promote deeper learning and sustainable professional behaviors across engineering and management contexts (Fontanella, 2025). Despite this growing body of evidence, many additive manufacturing courses continue to rely primarily on instructor-centered lectures, limiting opportunities for peer interaction, applied learning, and integration of design and fabrication experiences.

In response to these challenges, this paper describes the design, implementation, and evaluation of an interactive instructional strategy developed for a junior–senior level elective course in additive manufacturing. The instructional approach emphasizes student-led exploration, small-group discussion, peer-led micro-presentations, and hands-on design-to-print laboratory activities that directly connect theoretical concepts to physical fabrication. The purpose of this study is to examine how this approach influences student engagement, perceived learning, and instructional preference in an upper-level mechanical engineering course.

2. Course Context and Instructional Approach

The instructional strategy was implemented in MECH3800 Additive Manufacturing, a junior–senior level elective offered in Summer 2025. The four-credit course followed a combined lecture–laboratory format, consisting of two 75-minute lecture sessions and one 105-minute laboratory session per week. The course enrolled 31 students and required Engineering Graphics (MECH2300) or equivalent as a prerequisite, ensuring foundational CAD proficiency. Graded components included quizzes and homework (20%), laboratory assignments (30%), a midterm exam (20%), a final design project (25%), and participation (5%).

The course introduced core additive manufacturing (AM) principles with emphasis on design-for-additive-manufacturing (DfAM), process selection, file preparation and slicing, supports, post-processing, and process–material–property relationships. Major topics included CAD-to-CAM workflows, AM materials and technologies, fabrication considerations for FDM and PolyJet systems, and evaluation of mechanical performance. Students applied these concepts throughout the semester, culminating in a final design project requiring fabrication and comparison across AM technologies.

The interactive instructional approach was integrated throughout the semester and aligned with weekly content. Class sessions alternated between short instructor-led explanations, structured group discussions, and student-led micro-presentations. During discussion activities, students worked in small groups on focused prompts such as comparing AM processes, evaluating design trade-offs, and interpreting process–property relationships. Groups conducted rapid research, discussed findings, and delivered short presentations, followed by instructor-guided synthesis connecting student insights to key engineering concepts. These activities were intentionally linked to laboratory work, requiring students to apply discussion-based concepts in design-to-print tasks.

Students were primarily senior, with some junior mechanical engineering majors who had completed coursework in statics, mechanics of materials, and engineering graphics. While all students had prior experience with CAD modeling, most had limited exposure to additive manufacturing beyond introductory concepts. This diversity in background informed the use of structured group work, allowing students to collaboratively build understanding while leveraging peer-to-peer explanation and shared problem-solving.

2.1 Laboratory sequence and design-to-print innovation

Laboratories were structured as iterative design-to-print cycles in which students produced artifacts, evaluated outcomes, and communicated decisions. Early labs emphasized design constraints and manufacturability through a finite-volume challenge, where students designed a component within a 47.625 mm cube while considering orientation, supports, and material usage. A subsequent lab focused on technology evaluation, requiring teams to analyze an assigned AM system and design a demonstration part that highlighted its capabilities while estimating print time and cost.

Later laboratories emphasized process-specific design-for-additive-manufacturing (DfAM) decisions. For example, a PolyJet-focused lab required students to design multi-material components, select surface finish options, and justify design and orientation choices based on performance and manufacturability trade-offs. The course culminated in an individual final project in which students fabricated a design using two AM technologies and compared outcomes such as dimensional accuracy, surface quality, and post-processing effort.

To illustrate the range of activities, representative laboratory exercises included:

- **Finite-volume design challenge:** Constrained design within a fixed build volume with emphasis on orientation and support strategy
- **Technology evaluation lab:** Analysis of AM system capabilities and demonstration part design with cost/time estimation
- **PolyJet multi-material lab:** Design of multi-material components with surface finish and process trade-offs
- **Final design comparison project:** Fabrication using two AM technologies and comparative evaluation of performance and manufacturability

These laboratories were directly linked to classroom discussions, reinforcing the connection between conceptual understanding and physical fabrication.

3. Assessment Methodology and ABET Alignment

Student perceptions of the instructional approach were evaluated using an anonymous end-of-course survey consisting of three Likert-scale items and one open-ended prompt. Of the thirty-one students enrolled, twenty-six completed the survey, corresponding to an 84% response rate. The Likert-scale items measured perceived engagement, preference for interactive instruction relative to traditional lectures, and perceived improvement in understanding of AM topics. The open-ended prompt asked students what they liked most about the group discussion and presentation activity.

In addition to survey-based evaluation, course assessments were designed to support ABET Student Outcomes through aligned learning activities and deliverables. The instructional strategy emphasized (i) analysis of manufacturing and design trade-offs, (ii) design and optimization of AM-enabled components, (iii) technical communication via micro-presentations and lab reports, and (iv) iterative improvement based on fabrication outcomes. Graded components included quizzes and homework, laboratory activities, a midterm exam, a final project, and participation/attendance.

3.1 Mapping course outcomes to ABET Student Outcomes

The course learning outcomes and major deliverables align with ABET Student Outcomes as follows. This mapping is intended to clarify how the interactive activities and lab sequence support measurable skills associated with engineering practice.

Table 1. Course alignment with ABET Student Outcomes through learning outcomes and major assessments.

Course learning outcome / activity emphasis	ABET Student Outcome(s) most directly supported
Compare AM and conventional manufacturing processes; justify process selection using constraints and trade-offs	(1) solve complex engineering problems; (7) acquire new knowledge
Prepare files, plan supports, and evaluate post-processing needs based on process constraints	(1), (2) design solutions considering constraints
Differentiate AM technologies and match applications/limitations to engineering requirements	(1), (7)
Design and optimize assemblies for AM including supports, clearances, and functional requirements	(2) engineering design; (5) teamwork when completed in teams
Interpret material/process considerations and relate parameters to performance in printed parts	(1), (6) experimentation and interpretation (where testing/measurement is included)
Communicate technical decisions through micro-presentations, lab presentations, and final project reporting	(3) communication
Team-based labs requiring shared responsibility and collaborative decision-making	(5) teamwork

Assessment of ABET Student Outcomes was conducted through multiple graded components aligned with course activities. For example, Outcome (1) and (2) (problem solving and design) were evaluated through laboratory assignments and the final design-to-print project using rubrics that emphasized design justification, process selection, and performance evaluation. Outcome (3) (communication) was assessed through micro-presentations and final project reports, with criteria including clarity, technical accuracy, and ability to respond to questions. Outcome (5) (teamwork) was evaluated through group-based lab activities and peer feedback. Outcome (7) (lifelong learning) was reflected in student-led research during discussion activities, where students were required to independently explore and synthesize new AM topics. This multi-component assessment approach ensured that instructional activities were directly linked to measurable ABET outcomes.

Evaluation of the final design-to-print project was conducted using a structured rubric (Table 2) by multiple evaluators to ensure consistency and technical rigor. The rubric was applied independently by multiple evaluators, and scores were combined to ensure consistency and reduce individual bias. The evaluation team included the course instructor, an additive manufacturing laboratory technician with extensive hands-on experience, and an additional faculty member with expertise in additive manufacturing. The rubric assessed key criteria, including design complexity, application of DfAM principles, process selection and justification, print quality, and the ability to communicate design decisions.

Table 2. Final Project Evaluation Rubric.

Criterion	Description	Weight (%)
Design Complexity	Level of innovation and appropriateness for AM	20
DfAM Application	Use of orientation, supports, constraints	25
Process Selection	Justification of chosen AM technologies	15
Print Quality	Accuracy, surface finish, fabrication success	20
Communication	Clarity of presentation and technical explanation	20

4. Results

Survey results indicate strong student support for the interactive teaching strategy implemented in the additive manufacturing course. Of the thirty-one students enrolled, twenty-six completed the end-of-course survey, corresponding to an 84% response rate. Quantitative responses demonstrate consistently positive student perceptions across measures of engagement, instructional preference, and perceived learning.

Student engagement results show that a substantial majority of respondents felt more engaged during class sessions that incorporated group discussion activities, as shown in Fig. 1. Specifically, 46.2% of students strongly agreed and 42.3% agreed with the statement that group discussions increased their engagement, resulting in a combined positive response rate of 88.5%. The remaining 11.5% of respondents selected neutral, and no students reported disagreement. This distribution suggests that the interactive format was broadly effective in promoting student engagement, with no reported negative perceptions.

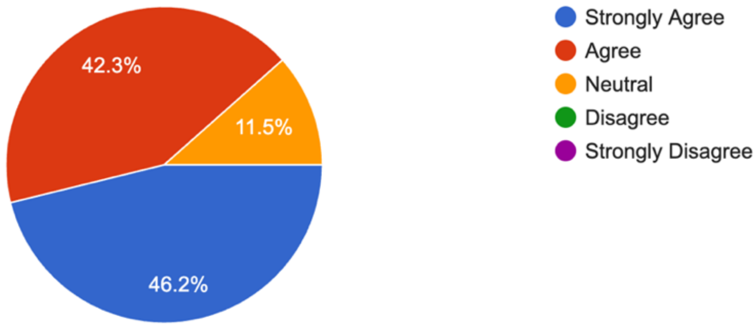

Figure 1. Student responses to the statement "I felt more engaged in the class through the group discussion activities" (n = 26). The majority of students reported increased engagement, with 46.2% strongly agreeing and 42.3% agreeing.

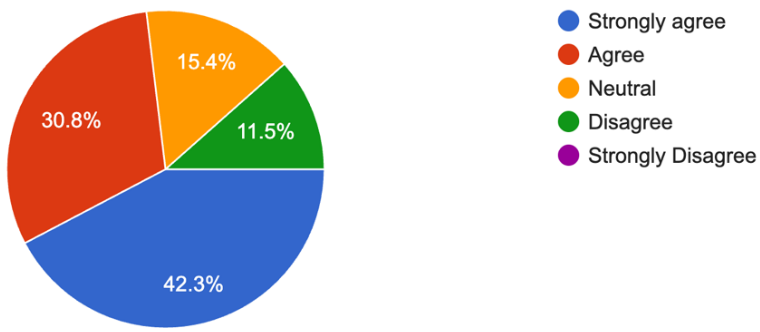

Figure 2. Student responses to the statement "I preferred this interactive method over traditional lectures" (n = 26). More than 70% of students agreed or strongly agreed, indicating a preference for the interactive instructional approach.

Student preferences regarding instructional format further support the effectiveness of the interactive approach. As illustrated in Fig. 2, 42.3% of respondents strongly agreed and 30.8% agreed that they preferred the interactive method over traditional lectures, yielding a combined preference rate of 73.1%. A smaller proportion of students (15.4%) reported neutral attitudes, while 11.5% indicated disagreement. Although a minority of students expressed preference for traditional lectures, the overall trend indicates that most students favored the interactive instructional model.

Perceived learning outcomes were similarly positive. As shown in Fig. 3, 50.0% of respondents strongly agreed and 34.6% agreed that in-class discussions helped them better understand the assigned additive manufacturing topics, resulting in an 84.6% positive response rate. Only 11.5% of students selected neutral, and 3.9% reported disagreement. The high proportion of strongly agree responses suggests that students perceived the discussion-based activities as particularly effective for conceptual understanding.

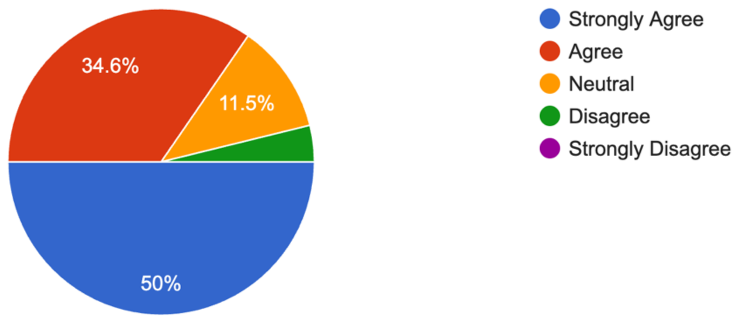

Figure 3. Student responses to the statement "The in-class discussions helped me better understand the assigned additive manufacturing topics" (n = 26). A strong majority of students reported improved understanding, with 50.0% strongly agreeing and 34.6% agreeing.

Qualitative survey responses provide additional insight into the sources of these positive perceptions and help contextualize the quantitative results. Analysis of the open-ended responses revealed several recurring themes demonstrated by multiple student comments. A large number of students emphasized that actively presenting and teaching a topic to peers reinforced their own learning, with several respondents explicitly stating that they learned the most from the topic they presented. This finding aligns with prior research on peer teaching and active learning, which suggests that explaining concepts to others promotes deeper cognitive processing.

Another prominent theme involved the value of peer interaction and collaborative learning. Many students highlighted the opportunity to exchange ideas, hear different perspectives, and learn from classmates' research. Several responses noted that discussing real-world examples and case studies helped make abstract or unintuitive additive manufacturing concepts more concrete. Students also reported that working in small groups made learning easier and more engaging compared to passive lecture environments.

Additional comments emphasized the benefits of focused topic assignments, rapid research, and short presentations. Students appreciated being assigned a narrow topic, which allowed them to explore specific additive manufacturing processes or design considerations in greater depth. Others highlighted the development of communication and teamwork skills, noting that the activities provided practice in quickly preparing and delivering technical presentations.

Although the majority of feedback was positive, a small number of students indicated a desire for fewer discussion activities or additional direct instruction. These responses suggest that while interactive learning was generally well received, an appropriate balance between instructor-led content and student-centered activities remains important.

In addition to survey-based findings, performance on the final design-to-print project provided complementary insight into student learning. Based on rubric-based evaluation by multiple evaluators, students demonstrated strong performance in applying DfAM principles and process selection, with most projects meeting or exceeding expectations in design justification and fabrication quality. The average final project score was 87%, with the majority of students scoring above 80% in design justification and fabrication quality. While performance varied across individuals, overall results indicated that students were able to effectively translate conceptual understanding into practical design and manufacturing outcomes.

Overall, the combined quantitative and qualitative results indicate that students perceived the interactive teaching strategy as enhancing engagement, supporting understanding of additive manufacturing concepts, and offering a more favorable instructional experience than traditional lecture-based instruction.

5. Discussion

The primary contribution of this work is the structured integration of three instructional elements: group discussion, student-led micro-presentations, and hands-on design-to-print laboratory activities into a unified and iterative learning cycle. While each of these elements has been explored individually in prior active learning and project-based learning literature, this study emphasizes their intentional coupling and alignment. In this framework, concepts introduced through rapid group discussion and peer explanation are immediately reinforced through laboratory design, fabrication, and reflection. This repeated connection between conceptual understanding and physical realization distinguishes the approach from traditional implementations of active learning or project-based instruction, where these components are often used independently. The result is a cohesive design-to-print learning cycle that supports both technical understanding and professional skill development in additive manufacturing education.

The results of this study indicate that students responded positively to the interactive teaching strategy and reported perceived benefits in engagement, instructional preference, and understanding of additive manufacturing topics. The high survey response rate supports the representativeness of the findings. Nearly 90% of students reported increased engagement during group discussion activities, with no negative responses, suggesting that the interactive format effectively supported sustained student involvement in complex additive manufacturing topics. In addition to these perception-based findings, rubric-based evaluation of the final design-to-print project indicates that students were generally able to translate conceptual understanding into effective design and fabrication outcomes. This alignment between perceived learning and demonstrated performance strengthens the overall interpretation of the results (Prince, 2004; Freeman et al., 2014).

Student preferences further support the effectiveness of the approach, with more than 70% of respondents indicating a preference for the interactive method over traditional lectures. While a small number of students expressed neutrality or disagreement, the overall trend suggests that students value opportunities to actively discuss and apply concepts, particularly in interdisciplinary and application-driven subjects such as additive manufacturing. These findings reinforce the importance of incorporating student-centered activities alongside concise instructor-led instruction.

Perceived learning outcomes were especially positive, with over 84% of students reporting that in-class discussions helped them better understand the assigned additive manufacturing topics. The high proportion of "strongly agree" responses suggests that discussion-based activities contributed meaningfully to conceptual understanding rather than serving as a supplemental engagement tool.

This observation is consistent with prior studies demonstrating that peer teaching and project-based learning promote deeper cognitive processing and knowledge integration (Ramanathan et al., 2025).

Qualitative responses help explain these outcomes by highlighting the value of peer interaction, focused topic exploration, and short presentations. Many students reported learning the most from the topic they presented, underscoring the effectiveness of peer-led learning. Students also emphasized the benefits of exchanging ideas, discussing real-world examples, and connecting theoretical concepts to hands-on design and fabrication activities. Together, these findings suggest that integrating structured group discussion, peer-led presentations, and design-to-print laboratory experiences can enhance learning in upper-level additive manufacturing education while supporting both technical and professional skill development.

A key innovation of the course design is the repeated coupling of discussion, micro-presentation, and laboratory fabrication within a single learning cycle. Rather than treating discussion as a standalone engagement activity, the implementation required students to operationalize the same concepts in physical prints, cost/time estimates, and comparative evaluation across technologies. This structure reinforces conceptual understanding through repeated application in design and fabrication tasks, providing a practical mechanism for linking active learning to authentic manufacturing constraints.

Unlike traditional implementations of active learning or project-based instruction, this approach systematically integrates peer-led discussion, micro-presentations, and fabrication-based laboratory work within a repeated cycle, ensuring that each conceptual activity is immediately reinforced through design, manufacturing, and reflection.

Importantly, this structure ensures that conceptual understanding is not only discussed but also tested and refined through physical fabrication, providing students with immediate and tangible feedback on design decisions.

6. Limitations and Future Work

This study is based primarily on self-reported survey data from a single course offering, which limits the extent to which the findings can be generalized or interpreted as direct evidence of learning gains. While the survey results provide useful insight into student perceptions of engagement, instructional preference, and perceived understanding, they do not directly measure content mastery or long-term retention.

In addition, although rubric-based evaluation of the final design-to-print project provides complementary evidence of student performance, these results are aggregated and do not isolate the specific impact of individual instructional components within the interactive framework.

Future work will incorporate more direct and comparative measures of learning, including exam performance, detailed rubric-based analyses across multiple course offerings, and comparisons with more lecture-centered instructional approaches, as well as longitudinal evaluation of student outcomes.

7. Conclusions

This paper presents an interactive teaching strategy for a junior–senior level additive manufacturing elective that integrates group discussion, micro-presentations, and design-to-print laboratory experiences. Student survey results indicate positive student perceptions of engagement, understanding, and preference for the interactive instructional format over traditional lectures. The findings suggest that structured, student-centered instructional strategies are promising for additive manufacturing education and may help support preparation for modern engineering practice.

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