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Undergraduate Research Discovery through Manufacturing Education: Assessing Near-Peer Mentorship as a Pathway to Graduate Research

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Abstract

This paper examines a research-based additive manufacturing (AM) course designed to support undergraduate engineering students' early discovery of research and graduate education pathways through structured near-peer mentorship. In the course, undergraduate students engage in semester-long, team-based AM research projects aligned with active laboratory investigations, while graduate students serve as near-peer mentors who provide technical guidance, research training, and professional socialization. Grounded in Self-Determination Theory, the study investigates how this learning environment supports students' autonomy, competence, relatedness, and emerging research identity. Survey data were collected from undergraduate participants enrolled in the course in Spring 2025 (N = 34) using Likert-scale and open-ended items measuring perceptions of course rigor, understanding of engineering research, graduate school intentions, and the influence of near-peer mentorship. Quantitative results indicate that 94% of students reported improved understanding of how engineering research is conducted, and 73.5% indicated that the course influenced their decision-making regarding graduate education, either by increasing interest or clarifying misalignment with research careers. Qualitative findings reveal that hands-on research experiences, exposure to graduate research environments, and continued interaction with graduate mentors were central in shaping students' confidence, self-efficacy, and career clarity. Findings suggest that embedding authentic research and near-peer mentorship within undergraduate AM coursework provides a powerful mechanism for helping students make informed career decisions while strengthening research preparedness and identity formation. Since inception, this course-based undergraduate research model has produced multiple refereed journal and conference publications co-authored by undergraduate research teams and graduate mentors, demonstrating that near-peer, team-based research integration is both pedagogically and professionally effective. This model offers a transferable approach for advancing manufacturing education and supporting the development of both undergraduate researchers and graduate student mentors.

1. Introduction

A person's career plays a crucial role in shaping identity, purpose, well-being, and social status. Choosing a career path is often a practical decision and identity-making process that develops gradually, requiring intentional support and structured opportunities to develop knowledge and skills in a chosen field. Research has shown that students gain confidence and clarity when they build technical skills, visualize themselves in a specific field, and receive scaffolding needed to explore their interests through coursework (Anderson et al., 2019). As critical as the choice of a career may be, many individuals do not have the opportunity to explore different career options with the necessary guidance before committing to one. Early exposure is especially important in engineering, where the discipline often requires entry-level specialization and a progressive mastery of skills, including extensive prerequisite coursework, technical proficiency, research skills, and discipline-specific competencies. Because of these requirements, students' early career decisions are critical to achieving a fulfilling career. When students identify their interests and long-term aspirations early, it helps prevent attrition, reduces time and resource wastage, and increases engagement in their chosen careers (Conner et al., 2024; Godfrey et al., 2010). Early career choices set students on long-term professional pathways, placing them on an appropriate academic track and helping develop a sense of professional identity (Anderson et al., 2019). Another important aspect of early career development is near-peer mentorship between undergraduate and graduate students. This type of mentorship helps students feel a sense of belonging and integration in research environments, broadening their participation and understanding of engineering (Gehreke & Kezar, 2024).

Moreover, research has shown that most engineering professionals remain in the field or specialty they first encountered during their academic training (Brunhaver, 2015). As students develop foundational experience and identity in a specific engineering field, they are more likely to continue that path rather than switch. A study by Spears (2025) strengthens this finding, showing that engineers rarely switch fields after their initial career choice due to the necessity for specialized expertise and the rewards for depth of knowledge. As a result, early specialization often locks individuals into specific fields, making career transitions challenging (Sheppard et al., 2009). In addition to these considerations about career trajectories, another field of interest in recent years has been developing the workforce to advance manufacturing in the United States (Al-Asfour, 2025; Colombari & Neirotti, 2022; Wosczyna-Birch & Robicheau, 2022). The weaknesses in the manufacturing supply chain revealed during the COVID-19 pandemic have necessitated these reshoring efforts. Given these trends, it is therefore important to provide students with multiple opportunities to interface with careers in advanced manufacturing. These opportunities demystify barriers, helping students make informed early career decisions that align with their interests.

This study examines one such opportunity for students to gain early career exposure in the advanced manufacturing field. Exploring research discovery in manufacturing education is vital, as it can influence students' self-esteem, self-efficacy, and early career identity in the field (Bandura, 1982). In this study, undergraduate students taking the undergraduate elective course on additive manufacturing (AM) at Purdue University in the spring of 2025 were allowed to conduct advanced AM research, supervised by a graduate peer mentor. The Additive Manufacturing Standards of the American Society of Testing and Materials (ASTM) defines AM, also known as 3D printing, as a "process of joining materials to create parts from 3D model data, typically layer upon layer.” This is a relatively young field of manufacturing with many techniques that are not fully understood. Students who took part in the course were guided in identifying research questions on AM techniques of interest and in developing research objectives. They were provided with the resources to investigate their research objectives through executing an experiment plan. Additionally, the findings of their research were organized into conference proceedings and posters presented at the Solid Freeform Fabrication Symposium annual conference. These structured programs were to introduce undergraduate students to potential graduate research career pathways. This study further investigates how undergraduate manufacturing engineering students discover research pathways and how near-peer mentorship guides them toward graduate-level research. Specifically, it aims to examine how a research-based AM course supports undergraduate identity formation through team-based research and structured mentorship. The course involves semester-long AM research challenges in laboratory settings, with graduate students serving as near-peer mentors offering technical guidance and research training. The AM class offers a distinctive intervention through its hands-on, design-centered methodology, which contrasts with traditional, theory-intensive engineering courses. These courses immerse students in a research-driven design process, enhancing their problem-solving abilities and rapid prototyping skills, to provide an authentic experience that introduces students to engineering careers early in their academic trajectories.

Despite the importance of retaining critical talents in manufacturing in the long term, few studies have examined how early exposure to AM coursework, combined with near-peer mentoring, shapes undergraduate engagement for research, pursuit of graduate school, and career clarity. This gap highlights the significance of additional research on methods to foster continuous engagement among undergraduate students in advanced manufacturing, such as course-based undergraduate research experiences and near-peer mentorship programs. Understanding the relationship that undergraduate research and near-peer mentorship have on student engagement is vital in a field where early career decisions shape long-term professional trajectories. Therefore, to address the study goals, the research questions guiding this study are:

1. To what extent does student participation in the research-based additive manufacturing course influence their interest in pursuing research careers?
2. To what extent does near-peer mentoring between undergraduate and graduate student researchers influence undergraduates’ intentions to pursue graduate education?
3. How do students describe the ways in which early exposure to engineering research careers and mentoring shapes their understanding of whether the AM field aligns with their goals and interests?

2. Theoretical Framework

2.1 Self-Determination Theory as a Lens to Understand Student Research Identity

In this study, we utilize the Self-Determination Theory (SDT), which is a theory that aims to describe the factors that contribute to motivation (Ryan & Deci, 2017). The theory is used to explain how the additive manufacturing course, combined with a graduate near-peer mentorship program, influences undergraduate students’ desire to pursue manufacturing research careers and graduate school, while strengthening their research identity and self-efficacy. Following SDT, students’ motivations are supported when individual students perceive their autonomy, feel competent in their abilities, and are able to meaningfully relate to their immediate environments (Ryan & Deci, 2000; 2020). It is therefore vital to analyze the mechanisms that influence the impact of the AM course on students' academic and research goals. SDT is an ideal analytical lens suited for this research topic, particularly because it emphasizes how a learning environment and relationships either support or restrain motivation and persistence.

This research included students who were engaged in authentic team-based research problems in active laboratories, working alongside graduate students, which makes the learning process feel personally meaningful and intellectually engaging. In the context of SDT, such a learning space can shift students' external motivations and demands (e.g., grades) into more self-determined forms of motivation (e.g., fulfillment, excitement, curiosity) to enhance their competence development and self-efficacy (Schunk,1991). In alignment with SDT, the AM course and near-peer mentorship provide authentic activity, social, and developmental conditions that support students' cognitive needs. In alignment with the study findings, SDT explains why near-peer mentorship is a key mechanism for influencing students' persistence towards graduate education. SDT recognizes that when students receive support, and their intrinsic or extrinsic motivations and needs are met, they are more likely to persist, view themselves as capable of pursuing graduate education, and develop confidence and identity through research in the field of manufacturing education (Strauss & Parker, 2014).

In summary, SDT is contextualized in this study to include autonomy (sense of choice), self-efficacy (beliefs in abilities), competence (capabilities), and relatedness (sense of connection and belonging) (Ryan & Deci, 2020). We utilize these components to investigate how an additive manufacturing college course, where undergraduate students participate in research alongside graduate students, sparks interest in research careers and graduate education. Grounding this study in SDT, it helps shed light on how the course boosts students' sense of control over academic choices, confidence in their abilities, and feelings of connection to their academic program.

3. Literature Review

Previous research has shown that one of the most impactful foundational approaches to career development in engineering is providing early exposure to hands-on research experience through coursework (Linn et al., 2015; Lopatto, 2017; Seymour et al., 2004). Course-based undergraduate research experience reinforces career development by socializing students through authentic scientific inquiry in collaborative, real-world settings (Mabrouk & Peters, 2000; Russell et al., 2007). Undergraduate engineering research courses familiarize students with the field's norms, expectations, and values, immersing them in scientific investigations alongside peers and faculty (Kardash, 2000; Zhan, 2011). Early exposure is vital so that undergraduates can make informed career decisions based on research opportunities or receive mentorship to spark their research interests or align their strengths with professional goals.

In addition to early research opportunities, near-peer mentorship, in which graduate students mentor undergraduate students, plays a role in shaping student identity, research interests, and persistence. In contrast to hierarchical faculty supervision, the student-mentoring approach positions the graduate and undergraduate students as both teachers and learners, creating a space for mutual learning (Rayford et al., 2022). The graduate student learns how to mentor students, and the undergraduate student learns the expectations of graduate studies. Another benefit of the near-peer mentoring program is its association with high rates of continued engagement and career persistence in engineering (Spaulding et al., 2020; Rayford et al., 2022). The mentor serves to help with identity development, building confidence in ways that sustain long-term career trajectories (Haeger & Fresquez, 2016). In a similar vein, Sabatti and Zhao (2025) and Zaniewski and Reinholz (2016) investigated the impact of near-peer mentoring in science programs where advanced doctoral students mentored undergraduate students early in their majors. The study found that mentoring relationships among graduate and undergraduate students increased belonging, academic success, and science identity, contributing to retention. At the same time, mentors themselves developed leadership skills and a sense of responsibility, which strengthened their communication with diverse learners and their commitment to the field of science (Sabatti & Zhao, 2025).

Internships, summer study abroad, and other structured programs have been examined as methods to support students' career readiness (Banker & Borchardt, 2025; Di Pietro, 2022; Gutiérrez-Pulido & Orozco-Rodríguez, 2025). Specifically, internships have been long investigated regarding their utility for providing valuable exposure and may help students understand workplace norms and expectations, but often only provide students with a surface-level view of engineering practice, which may not fully develop engineering identity or research preparedness (Ozek, 2018; Schnoes et al., 2018). In addition, structured programs like summer study abroad enhance research skills, collaboration, and communication, yet only deliver short-term training (Klahr & Ratti, 2000). While valuable, preliminary research indicates that such experiences are insufficient to support long-term professional development and identity formation (Parkinson, 2007). In all these studies, the potency of near-peer mentorship when embedded in undergraduate research experiences has not been adequately investigated. While Atkins et al. (2020) have shown that high-quality mentoring predicts growth in science and engineering identity and self-efficacy, which in turn predicts students' integration into future careers, mentoring in the field of additive manufacturing research has not yet been explored.

From this perspective, this study extends prior work to specifically examine how additive manufacturing programs with research-intensive courses, along with near-peer mentoring, increase students' interest in graduate education and research careers. This focus will not only fill a gap in engineering scholarship but also contribute to a broader conversation about how well-designed learning environments and structured mentoring models can help develop the next generation of engineering professionals.

4. Methods

The dataset consists of survey responses from a cohort of undergraduate students in the spring of 2025 (N = 34) at Purdue University who took the research-based additive manufacturing course in mechanical engineering. Surveys were administered at the end of the semester following completion of the research project. Using a 5-point Likert scale and open-ended items, the instrument was designed to measure students' perceptions of the rigor of the course, their understanding of the research-based additive manufacturing course, the course's influence on graduate-school intention and career identity, and the influence of near-peer mentorship on their academic and career preparedness. These items were designed to measure the degree to which respondents agreed or disagreed with specific statements, enhancing response reliability and capturing differences in attitudes and perceptions. Descriptive statistics were used for Likert items. The quantitative item scale included the following options: strongly agree, somewhat agree, neither agree nor disagree, somewhat disagree, and strongly disagree. Qualitative responses were analyzed thematically. The open-ended qualitative response invited participants to explain their reasoning behind their responses, providing contextual depth to reveal students' interpretations of the AM course, research experiences, and career decision-making. Together, the closed and the open-ended Likert-scale items capture students' meaning-making of the experiences in the AM courses and their perceptions of the impact of near-peer mentorship.

5. Results and Discussions

Participants described the AM course as more rigorous and research-intensive than other engineering classes, noting that the volume of lab work and project assignments contributed to a demanding workload. On the other hand, 90% of students' responses indicated that the AM course improved their understanding of how engineering research is conducted, which influenced their thinking about graduate school, whereas other students reported otherwise. Below is a description of the study findings based on students' responses.

5.1 Perceived Rigor of Additive Manufacturing Research-Based Course

Figure 1 presents the distribution of responses (N = 34) from undergraduates to the prompt, "*This course was more rigorous than my other mechanical engineering elective courses.*" This question aimed to capture students' perceptions about the rigor of the research-based additive manufacturing course compared to other manufacturing engineering courses. Students' responses range from strongly agree to neither agree nor disagree. The data indicate a perception that the course is more intensive than typical manufacturing classes, reflecting the higher cognitive load and time commitment associated with research-based learning. The data indicate that more than half of the students (N = 19, 56%) found the AM course to be more demanding than other mechanical engineering electives. These students responded to "somewhat agree" or "strongly agree" (Figure 1), while the remaining 46% responded with "somewhat disagree" (N=9) or "neither agree nor disagree" (N=6). No response to "strongly disagree" was recorded.

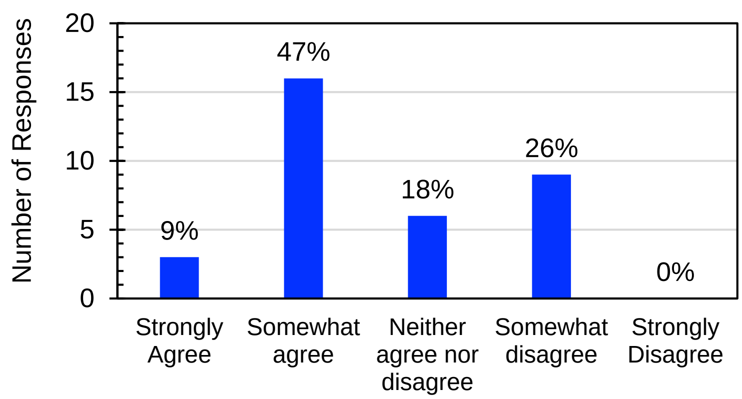

Figure 1 Distribution of student responses (N=34) on the perceived rigor of the research-based additive manufacturing course. Results indicate that 56% of students perceived the AM coursework as rigorous.

Participants' written responses provide additional nuances, including varied interpretations of rigor, differences in research exposure, shifts in engineering identity, and the important role of near-peer mentorship in guiding students toward research. The qualitative responses further captured students' perceptions of the course rigor. Students who described the course as more intensive attributed their perceptions to its research-driven nature. They typically attributed the intensity of the research focus course to three main reasons: understanding course requirements and expectations, committing time and effort, and engaging in critical thinking. One student added, "This course involved a hands-on research component that pushed me out of my comfort zone." In contrast, students who viewed the course as less intensive assessed the level of rigor in terms of the number of exams, the workload, and the conceptual difficulty of the lectures. These students explained that the conceptual scope was comparable to that of other engineering courses they had taken, that there was only one exam, and that homework was lighter. These variations indicate that, while the course introduced students to authentic research practices, their interpretations of rigor are deeply shaped by their cognitive understanding of the course content and classroom experiences. Overall, the responses of students demonstrate that the claim of increased rigor is true for most, but experiences differ depending on how students define rigor.

To better understand these findings, students' perceptions of the rigor of the AM research course can be examined through the lens of SDT. As described, SDT explains that individual motivation increases when three basic needs are satisfied. The first is autonomy, which highlights how individuals have control over their own choices and actions (Ryan & Deci, 2020). The second is competence, that is, the ability to develop skills and feel capable of achieving goals, and the third is relatedness, which is having a sense of belonging. When these needs are met, individuals are more likely to stay motivated, engaged, and satisfied in what they do. According to students' responses, autonomy emerges as the most prominent need reflected in the findings. The research-based AM course increased student autonomy by requiring greater self-regulation, as students were responsible for directing their own learning processes with the help of near-peer mentors. Here, students' cognitive load was higher, not because of how rigorous the class was, but because they were accountable for navigating ambiguity and making independent decisions.

5.2 Understanding of Engineering Research

Figure 2 presents a distribution of students' responses to the prompt "*This course improved my understanding of how engineering research is conducted compared to other engineering courses.*" The results showed a positive pattern, demonstrating a depth of understanding of engineering research. Findings revealed that out of the 34 responses, students who responded "strongly agree" included 20 responses (59%), students who responded "somewhat agree" included 12 responses (35%), and students who responded "somewhat or strongly disagree" included 2 responses (6%). Thus, about 94% of the participants agreed that the additive manufacturing engineering course enhanced their understanding. With approximately 59% of students strongly agreeing, and 35% somewhat agreeing, that the course improved their understanding, illuminating that the majority experienced transformative gain, while only 6 % expressed disagreement. This high level of agreement and minimal negative responses indicate that the course successfully met its goal of improving student understanding, possibly due to its emphasis on laboratory exercises and problem-solving skills.

Building on the previous findings, qualitative responses from the survey provide strong evidence that students perceive the research-based additive manufacturing course improved their understanding of engineering research. Three main reasons for how the course enhanced their understanding emerged from their open-ended responses: first-time exposure to authentic research, working alongside graduate near-peer mentors who provided structural support, and the development of cognitive and procedural skills. For many students, the course was their first introduction to research, where they learned laboratory techniques, and many described it as a meaningful departure from traditional teaching-based courses.

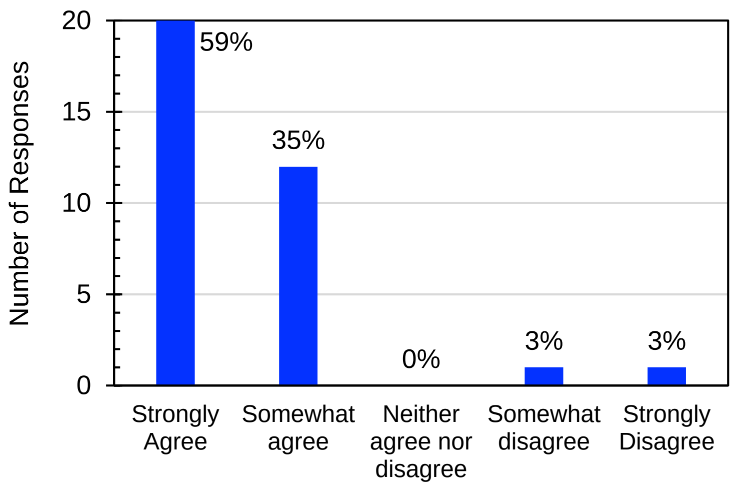

Figure 2 Distribution of student responses (N=34) on the students' understanding of engineering research expectations.

Following the first theme, "first-time exposure to authentic research," most respondents explicitly stated that they had "never had any previous experience with research" and that it was "their first time doing research." One student shared that the AM course was different from other engineering courses because its design helps them apply principles to solve defined problems and create new solutions. Students observed that the course filled an informational gap in the engineering curriculum by allowing them to engage in knowledge creation and problem-solving, rather than focusing solely on the computational or mathematical aspects typical of most undergraduate courses. Another recurring theme was the importance students placed on clear instructional scaffolding and the chance to conduct research with a graduate student mentor. Several students emphasized that learning alongside graduate students gave them practical insight into what research entails, demystified the research culture, and reduced intimidation, enabling them to model behaviors of advanced researchers in the field. One student also noted that the mentorship, along with guidance from the instructor, helped them navigate the complexities of research. Lastly, students reported gains in both cognitive and procedural research skills, sharing that they learned to think critically about research questions, conduct literature reviews, design experiments, and interpret findings. These student accounts demonstrate that the AM course provided them with meaningful research skills that improved their understanding of engineering research.

On the other hand, only two students disagreed that the course improved their understanding of the research-based course; neither response stemmed from poor instructional quality. While one student gave no clear justification for disagreeing, the other students expressed that “there was no comparison between other courses,” which highlights a misalignment with expectations and experiences, or disagreement closely tied to individual background. Thus, the results strongly support the argument that the AM course significantly benefits students, particularly in terms of research identity formation, cognitive development, and motivation towards graduate-level research.

5.3 Consideration of Graduate School in Engineering and how the AM Course Influenced that Decision

To better understand how students think about graduate school and how the AM course influences these considerations, students were further asked whether they have considered graduate school in engineering, and, if so, why and why not. This question was designed to explore students’ perspectives on participation in manufacturing education fields. From a total of thirty responses from 34 students, it was a nearly even split: 16 YES responses (53.3%) indicated that students considered graduate school, while 14 (46.7%) of students had not considered graduate school. The YES group included conditional, tentative, and other positive responses; the NO group included strong and conditional replies (wanting more industrial experience).

This balanced distribution suggests a diverse range of motivational positions informed by career goals, identity development, and personal circumstances. Students’ qualitative insights reveal that the AM course may influence decision-making by causing students to reflect on their goals, supporting the development of a research identity, or prompting a preference for non-research or industrial careers due to structural barriers and personal experiences. Students who had considered graduate school expressed interest in advanced study, noting a desire to gain mastery and deep engagement with research beyond the undergraduate curriculum. Many described the AM course as their first authentic experience with near-peer mentors and exposure to research, which increased their sense of preparedness for graduate school. In contrast, students who had not considered graduate school reported reasons tied to personal circumstances, career identity, and perceptions of research. Specifically, some shared a strong preference for industry, academic fatigue, and a desire to end their education, financial barriers, and dissatisfaction with the engineering curriculum and research identity alignment. This contrast highlights the need to understand the structural constraints shaping student decisions about advanced education and their broader impact on the engineering field.

5.4 Influence of the AM Course on Graduate School Interest

Drawing on students’ responses, this section emphasizes that the AM course and the structured near-peer mentoring influenced their motivation to either opt in or out of graduate studies in engineering. Figure 3 presents a distribution of responses to the item: “*This course influenced my interest in pursuing (or not pursuing) graduate studies in engineering. That is, this course helped me make an informed decision about my interest to pursue (or not) graduate education.”* Among the 34 respondents, 13 selected “strongly agree,” 12 selected “somewhat agree,” 9 selected “neither agree nor disagree,” 2 selected “somewhat disagree,” and 1 selected “strongly disagree.” Overall, 73.5% (25 students) indicated the AM course influenced their graduate school decision: 25 responses showed a positive influence, 9 were neutral, and 3 indicated a negative influence. Notably, the majority reported a shift in their thinking after taking the course; some became more interested in graduate study, while others realized it did not align with their expectations or interests.

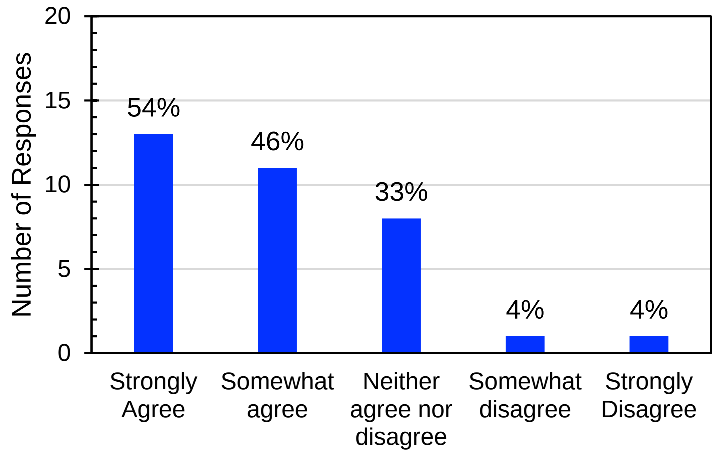

Figure 3 Distribution of student responses (N=34) on interest in pursuing (or not pursuing) graduate studies in engineering.

To delve deeper, a qualitative interpretation of how and why the course influenced students' decisions clarifies these nuances. Findings suggest that the research-based AM course provided informative experiences, helping students make decisions about graduate school. This course served as an identity-shaping intervention that supported career development. Specifically, three themes emerged from student responses: (1) increased interest in graduate studies, (2) reinforced disinterest in research, and (3) hesitation about graduate school despite interest in doing research. Each theme captures a distinct way the course influenced students' thinking and decisions.

A substantial number of students indicated that the course increased their interest in pursuing graduate education, especially given their prior lack of exposure to graduate environments or hands-on research. One student said, "I was somewhat sure about pursuing graduate studies before, but this course solidified that decision." Another added, "previously, I had little interest in pursuing graduate studies. After having taken part in this class, however, I definitely do want to pursue more research as part of graduate studies." Such reflections show that the course, by providing mentorship and hands-on experience, demystified graduate research and reduced uncertainty, encouraging students to view graduate degrees as attainable. For example, as one student described, "It has you working in grad spaces and with grad students on projects, so you got a good sense of what it might be like full-time."

On the other hand, a subgroup of students reported that, although the course did not increase their interest in graduate research, it clarified that graduate education was not the right path for them. This finding is significant because the course functioned as an exposure-based experience, helping students avoid misaligned educational and career goals upon entering graduate school. One student wrote, "this course showed me that I would not like to pursue graduate school, as research is not what I am interested in." Another explained, "to be honest, the research project portion of this course was very frustrating…If that is a sign of what research in grad school is like, it would deter me." For these students, the challenging nature of research revealed the realities of graduate-level work, reinforcing their disinterest in graduate education. Thus, early, firsthand experience helps students make well-informed choices grounded in authentic insights. Lastly, some students expressed contradictory feelings: they enjoy research but are hesitant about the demands of the graduate program. A student shared their hesitancy in this regard: "I like the research aspect and trying to find something new based on research already done, but don't want to do more school." Relatedly, another noted, "while I found this interesting, research is ultimately not my direction." These responses reveal that for these groups, the course increased awareness about graduate school but not interest in graduate research or studies. Together, responses indicate that the research-based AM course helped students clarify their career direction. Importantly, SDT provides a useful framework for explaining how the research-based AM course influenced students' decisions about graduate school. Students who reported heightened interest in graduate education likely experienced strong satisfaction with autonomy, competence, and relatedness. Overall, 73.5% of students reported that the course influenced their thinking about graduate education, whether positively or negatively. SDT helps explain why influence does not necessarily mean increased interest; rather, the course appears to have facilitated more self-determined decision-making. As a result, this sense of motivation helped students see themselves continuing in research-focused settings.

6. Limitation

This study presented two important limitations, including longitudinal tracking of participants' academic and career trajectories and the model's sustainability. Longitudinal tracking of participants' academic and career trajectories was not conducted within the current study timeline. The primary focus of this study was to examine the short-term impacts of how a research-based AM course supports undergraduate engineering students' early discovery of research and graduate education pathways through structured near-peer mentorship. The goal of the model was to help students make an informed decision about research careers and graduate school. From this perspective, collecting survey data at the end of the semester, when most students were seniors or juniors, was a suitable methodological approach. While the current data does not capture long-term outcomes, they are commonly used to evaluate shifts in intentions and informed decision-making, which are theoretically linked to later educational and career pathways. The data show that participants at Purdue University reported strong intentions to pursue graduate school; however, systematic longitudinal data collection was beyond the scope of the current study. This represents an important limitation, and future research will incorporate structured follow-up, such as alumni surveys or institutional data, to assess longer-term trajectories.

Furthermore, the scalability of the model to incorporate large cohort sizes is another potential for its broader implementation. The program is inherently resource-intensive and relies on constant engagement from faculty and graduate near-peer mentors. Expanding to significantly larger cohorts without additional resources may compromise the model's quality. To preserve meaningful mentorship and interaction, cohort size was intentionally capped at approximately 30 students per semester with six graduate student mentors and a principal investigator.

Nonetheless, this model is designed to be transferable and can be adapted across different engineering disciplines, especially within elective courses, where the cohort size is relatively small to better support students in exploring and deciding potential career pathways.

7. Conclusions

Our investigation supports the need to introduce students to potential career pathways to help them make informed career decisions. Using AM coursework with a research project component, supervised by a master's or PhD student, participants were queried on how the course structure influenced their decision regarding a graduate studies career path. The responses indicate that structuring a class with intentional scaffolding systems towards career pathways promotes understanding of fundamental concepts while exposing students to future potential career fields. The three key takeaways include the following:

1. Undergraduate research embedded in AM coursework supports informed career decision-making.
2. Near-peer mentorship operationalizes SDT constructs in engineering education.
3. The model benefits both undergraduates and graduate mentors.

From this study, about 74% responded positively to pursuing graduate engineering research because of the research experience of the AM class. Although approximately 9% of the students responded negatively to pursuing engineering graduate research, that decision was influenced by their research experience in that class. Thus, regardless of students' decisions about graduate studies, the course helped them make informed career decisions. Employing the SDT framework, this study proposes that the increased interest of students in future engineering graduate research can be explained by the intentional scaffolding systems that promoted autonomy, competence, and relatedness in a demanding academic context. Although the students perceived the AM course as rigorous, that did not undermine motivation because rigor was paired with support systems that affirmed the ability of students to succeed. Opportunities to chart meaningful research directions reinforced autonomy, easily accessible guidance, and feedback from mentors strengthened competence. Also, the persistent interactions with near-peer graduate mentors during research and general lab social events enhanced relatedness and belonging.

The practices programmed into the course further reinforced high-quality motivation. Adapting extrinsic motivators like presenting research at conferences, coauthoring journal manuscripts, and opportunities for research assistantships and fellowships were not only controlling incentives but also internalization mechanisms. These extrinsic motivators helped students connect immediate efforts to long-term academic and professional goals. Similarly, intrinsic motivators like curiosity, problem-solving, and interests in 3D printing were nurtured through authentic research work that was fulfilling to students. Easy access to near-peer mentors was crucial in bridging the motivation mechanisms needed for student success. These mentors helped the student participants to navigate research challenges, were role models for graduate studies, and strengthened the sense of belonging in the research community. From the SDT point of view, the careful alignment of supportive social contexts, extrinsic and intrinsic motivators, and the fulfillment of the psychological needs of the student participants explains why these students persisted in a rigorous course and excelled in their research. The scaffolding systems were critical to students envisioning themselves in an engineering graduate research career path.

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