# WIP: Where Peer Mentoring Flourishes: A Literature Review of First-Year Undergraduate Student Experience in STEM Makerspace and Design Learning Environments

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## Introduction

Retaining students in engineering remains a persistent challenge, with almost fifty percent of students ultimately switching to non-engineering majors before graduation, and most of this attrition occurring during the first year [1]. Research on engineering attrition shows that many students leave due to unwelcoming classroom climates, lack of belonging, low confidence, and limited access to role models or meaningful learning experiences [2]. These challenges are not solely academic in nature, highlighting that improving student persistence requires attention not only to technical preparation, but also to the social and experiential dimensions of learning in engineering education. To counter these challenges, several beneficial retention strategies were identified, such as first-year seminars or introductory engineering courses, collaborative and cooperative learning, hands-on design projects, and mentorship [2].

In response to these challenges, engineering educators have increasingly adopted instructional approaches that emphasize collaboration, hands-on learning, and early exposure to authentic engineering practice. Makerspaces, design studios, and project-based learning courses are now common features of first-year engineering curricula [3], [4]. These environments are designed to engage students in designing, building, and problem solving while working alongside peers. Research suggests that such environments can support student motivation, confidence, and engagement by making engineering learning more tangible and relevant [5], [6]. However, these settings can also be complex and intimidating, particularly for novice students who may lack prior experience, confidence, or familiarity with engineering tools and norms.

Within these collaborative learning environments, peer mentoring has emerged as a promising instructional strategy for supporting student participation and persistence. Peer mentors, often students who have previously completed the course or who have more experience with the learning environment, occupy a unique position between instructor and learner. They can provide academic guidance, model engineering practices, and offer social support in ways that feel accessible and relatable to first-year students [7], [8]. Prior studies have documented that peer mentoring can support student engagement, reduce anxiety, and foster a sense of belonging, particularly in early engineering courses [6], [9]. Despite these benefits, the role of peer mentoring in makerspaces, design studios, and project-based learning environments is not yet well synthesized across the literature.

Existing research on mentoring in engineering education tends to emphasize faculty-led mentoring programs or single institution program evaluations [10], [11], [12]. While these studies provide valuable insights, they offer a partial view of how peer mentoring functions across different instructional contexts and how it supports learning beyond academic performance alone. There is a need for a review that brings together empirical studies on peer mentoring in hands-on engineering environments to examine where peer mentoring occurs, how it is structured, and what learning outcomes are emphasized. Such a synthesis can help clarify the instructional value of peer mentoring and inform more intentional design of mentoring structures in early engineering education.

This literature review focuses on peer and near-peer mentoring embedded within makerspaces, design studios, and project-based learning courses in undergraduate engineering education. The review is guided by learning outcomes related to student engagement, sense of belonging, and engineering identity development. Rather than treating mentoring as an add-on support, this work examines peer mentoring as an instructional strategy that shapes how students participate in engineering learning environments.

To support this analysis, the review draws on sociocultural perspectives of learning, specifically Situated Learning Theory [13], Communities of Practice [14], and Social Cognitive Theory [15]. These theories provide lenses for understanding learning as a process that occurs through participation, observation, reflection, and interaction within a social context. They help explain how peer mentoring may support student learning by providing access to authentic practice, opportunities for meaning-making, and relational support within engineering communities [16], [17].

The purpose of this review is to synthesize existing empirical research on peer mentoring in makerspaces, design studios, and project-based learning environments in undergraduate engineering education. By examining how peer mentoring is implemented and what outcomes are reported, this review aims to identify patterns, gaps, and opportunities for strengthening instructional practices.

## Methodology

A scoping literature review approach was used to examine how peer mentoring functions within makerspaces, design studios, and project-based learning environments in undergraduate engineering education. This review was guided by the scoping review framework proposed by [18], which emphasizes mapping the breadth of existing literature, clarifying key concepts, and identifying gaps in knowledge rather than evaluating intervention effectiveness. Reporting of the search and screening process aligns with the PRISMA Extension for Scoping Reviews (PRISMA-ScR) to support transparency and reproducibility in study identification and selection.

The literature search was conducted during a single review period as part of a course-based scoping review and was limited to studies published between 2015 and 2025 to capture recent and relevant work in engineering education. This approach was selected to map existing research, identify patterns and gaps, and synthesize how peer mentoring is conceptualized and implemented across instructional contexts, rather than to evaluate the effectiveness of a single intervention.

### *Databases*

The databases ERIC (via ProQuest) and ASEE PEER were selected for this review due to their wide coverage of education research and engineering education conference proceedings, respectively. ERIC was used to identify peer-reviewed journal articles and conference papers situated in education and learning sciences, while ASEE PEER was used to capture engineering education research that is frequently disseminated through conference venues and may not yet appear in journal publications.

In ERIC, filters were applied to restrict results to English-language, peer-reviewed journal articles and conference papers focused on higher education or postsecondary education. ASEE PEER searches were limited by publication year and manually screened based on titles and abstracts.

*Identification of Keywords*

Search terms were identified based on six concept clusters central to this review: (1) mentoring roles, (2) instructional context, (3) learner population, (4) disciplinary framing (engineering/STEM), (5) learning outcomes, and (6) learning theory. Because terminology varies across engineering education and STEM education literature, multiple related terms were used within each category as shown in Table 1. Quotation marks were used for exact phrases, and asterisks were used to capture variations of root words.

**Table 1. Key Term Categories Used in the Literature Search**

| Concept Cluster | Example Keywords |
|---|---|
| Mentoring roles | "peer mentor*", "near-peer mentor*", "peer mentoring", "learning assistant", "peer leader", "peer teaching" |
| Instructional context | makerspace*, "design studio", "fabrication lab", "project-based learning" |
| Learner population | undergraduate, "first-year students", "novice engineers" |
| Disciplinary framing | "engineering education", STEM |
| Learning outcomes | identity, belonging, engagement, "professional identity" |
| Learning theory | "social cognitive theory", "community of practice", "situated learning", "situative learning" |

*Search Strategy and Boolean Logic*

Rather than relying on a single comprehensive search string, multiple searches were conducted to account for differences in terminology across databases and publication venues as shown in Table 2. Boolean operators ("AND," "OR") were used to combine terms, and searches were iteratively refined based on initial results.

**Table 2. Example Search Strings Used in ERIC and ASEE PEER**

| Database | Example Search String |
|---|---|
| ERIC (ProQuest) | (“peer mentoring” OR “near-peer mentoring” OR “peer teaching” OR “learning assistant”) AND (“engineering education” OR STEM) AND (identity OR belonging OR engagement) |
| ERIC (ProQuest) | (“peer mentoring” OR “peer learning”) AND (observation OR participation OR reflection OR modeling) AND (“engineering education” OR STEM) |
| ASEE PEER | (“peer mentor*” OR “near-peer mentor*” OR “learning assistant”) AND (makerspace OR “design studio” OR “fabrication lab” OR project-based learning”) AND (identity OR belonging OR engagement) AND ("social cognitive theory" OR "community of practice" OR "situated learning") AND ("engineering education" OR STEM) AND ("first-year students" OR "novice engineers" OR "undergraduate") |
| ASEE PEER | peer mentor* AND (undergraduate OR “first-year”) AND (makerspace OR “design studio” OR “project-based learning”) AND (identity OR belonging OR "professional identity" OR engagement) |

Across all searches, ERIC returned 79 records, and ASEE PEER returned 1,798 records, for a total of 1,877 initial results prior to screening. The screening and selection process is documented using a PRISMA-ScR flow diagram, which details record identification, abstract screening, exclusions, and final study inclusion.

*Study Selection and Screening*

Following the identification of records, a multi-stage screening process was used to determine study eligibility. This process aligns with the study selection phase described by [18] and is reported using PRISMA-ScR guidelines to ensure transparency in inclusion and exclusion decisions. The screening process focused on identifying studies that meaningfully addressed peer mentoring within early undergraduate engineering learning environments and examined learning or developmental outcomes relevant to this review.

Titles and abstracts of all identified records were first reviewed to assess relevance. Studies were retained for further consideration if they met the following inclusion criteria:

1. focused on higher education engineering or STEM contexts,
2. involved peer mentoring or functionally equivalent near-peer instructional roles (e.g., learning assistants, peer leaders, peer teachers),
3. examined participation, identity, belonging, or engagement, and
4. were situated within makerspaces, design studios, project-based learning courses, or closely related hands-on instructional environments.

Studies were excluded during this stage if they focused exclusively on K-12 settings, graduate-only populations, professional development contexts without undergraduate learners, or did not involve peer-based instructional or mentoring roles. Conceptual papers, opinion pieces, and reports without empirical data were also excluded. Full-text screening was then conducted for studies that met the initial criteria. During this phase, additional exclusions were made when studies lacked sufficient alignment with the instructional contexts of interest or did not examine outcomes relevant to engagement, belonging, or identity development. While some studies described collaborative or active learning environments, they were excluded if peer mentoring did not play a meaningful role in the instructional design or learning experience.

Importantly, studies were not excluded solely because they did not explicitly reference a formal learning theory. Consistent with scoping review methodology, papers were retained if they examined peer mentoring practices and outcomes that aligned conceptually with sociocultural learning perspectives, even when theory was implicit rather than explicitly named. The final set of studies included 17 studies that met all inclusion criteria and were retained for data charting and synthesis. The full screening process, including reasons for exclusion at each stage, is summarized in the PRISMA-ScR flow diagram (Figure 1).

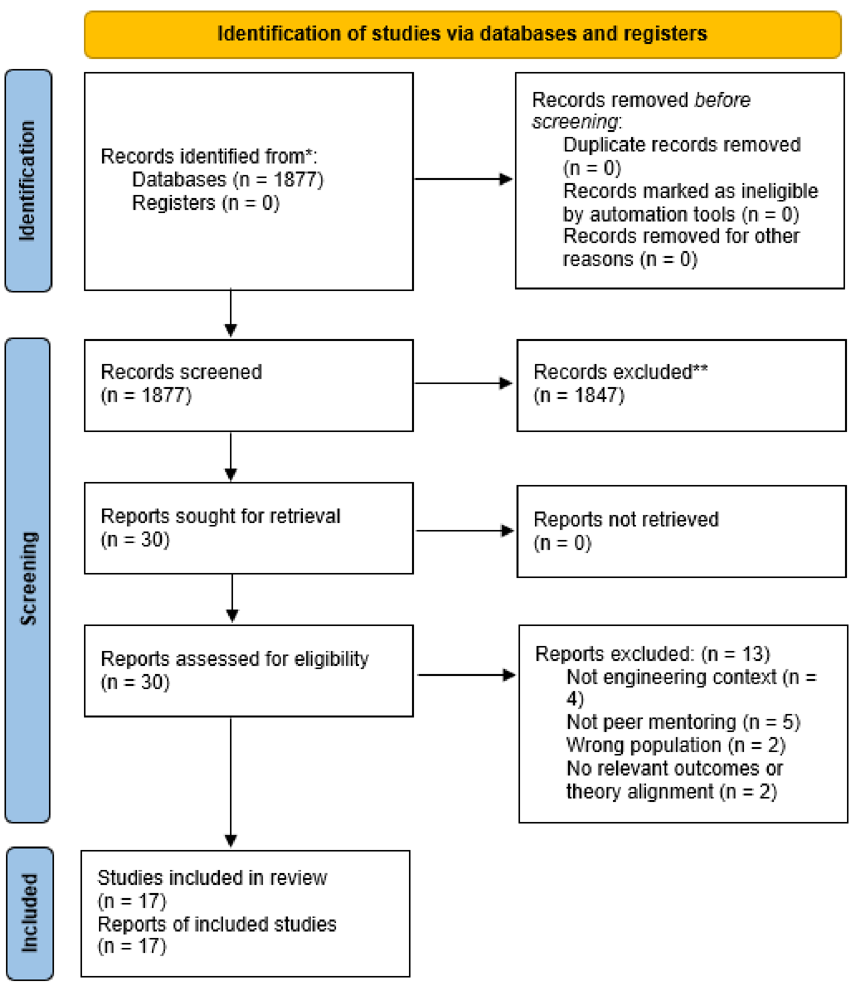


**Figure 1. PRISMA-ScR Flow Diagram for Study Identification and Selection**

**Preliminary Results**

Across the 17 included studies, peer mentoring was consistently situated within hands-on, collaborative engineering environments, most commonly first-year design courses, makerspaces, and project-based learning contexts. Several studies explicitly focused on first-year engineering courses that incorporated peer mentors as part of the instructional structure rather than as an external support service [6], [19], [20], [21]. In these settings, peer mentors were embedded within classrooms or learning spaces, supporting students during design activities, fabrication tasks, and team-based work. Other studies extended mentoring beyond a single course through multi-tiered or programmatic models, such as cascaded mentoring structures or integrated community courses [19], [22], [23]. While the instructional contexts varied, all studies positioned peer mentoring within environments that emphasized active participation and authentic engineering practice.

The structure of peer mentoring roles varied widely, both in title and in degree of formalization. Mentors were described as peer mentors, learning assistants, teaching fellows, peer leaders, or student instructors, often without a consistent distinction between mentoring and instructional responsibilities. This lack of distinction suggests that peer mentoring is not clearly defined across studies, with many roles functioning more as instructional support than as relational mentoring. For example, [20] examined how peer mentors in first-year engineering courses navigated ambiguity between being “friendly mentors” and acting as former consultants, noting that mentors themselves struggled to define their role boundaries. Similarly, [24] described a students-teaching-students model in a capstone design context, where peer instructors supported teams academically while simultaneously developing their own learning and leadership skills. Across multiple studies, mentors were typically students who had previously completed the course or had significant experience in the learning environment, reinforcing the near-peer nature of these roles [21], [25].

Preparation and training for peer mentors were inconsistent across studies. Some papers reported structured onboarding or mentor preparation processes, often focused on logistics, expectations, or communication strategies [10], [19]. Others indicated that mentors learned their roles primarily through experience, observation, and interaction with students and instructors [7], [26]. Several studies explicitly acknowledged that mentors were learning “on the job,” developing confidence, agency, and professional skills through their mentoring experiences rather than entering the role fully prepared [27], [28]. This variability suggests that peer mentoring is often implemented pragmatically rather than through theoretically grounded or standardized training models.

In terms of student outcomes, engagement was the most consistently reported outcome across the literature. Engagement was described through increased participation in class activities, greater willingness to ask questions, and sustained involvement in design or making tasks [6], [23], [29]. Several studies noted that the presence of peer mentors lowered barriers to participation by making help feel more approachable and reducing intimidation associated with instructors or unfamiliar tools [25], [30]. In makerspace contexts specifically, mentors were described as critical for helping students feel comfortable entering and using shared spaces, which supported continued engagement over time [21], [30].

A sense of belonging was also reported in multiple studies, though often indirectly. [31] found that teaching fellows contributed to students’ feelings of belongingness and esteem, particularly when mentors were visible and consistently present. Similarly, [32] described peer mentors as "social support catalysts" who helped students feel welcomed and supported within a multidisciplinary first-year design course. Studies that emphasized community-building elements, such as structured cohort models or integrated community courses, more explicitly linked mentoring to belonging outcomes [23], [26]. However, belonging was rarely operationalized through formal measures and was more often inferred from student perceptions or qualitative feedback.

Engineering identity development appeared less frequently and less explicitly across the literature. [10] offered one of the most direct examinations of identity, proposing a formal model for informal peer-to-peer mentorship aimed at supporting lower-division students' development as engineers. Other studies referenced identity implicitly, describing students beginning to see themselves as capable contributors or legitimate participants in engineering practice [19], [33]. Notably, identity outcomes were more often discussed in relation to mentors than mentees, with several studies highlighting how serving as a peer mentor supported mentors' own professional identity, confidence, and persistence in engineering [7], [28].

Across the corpus, explicit use of learning theory was limited, despite strong conceptual alignment with sociocultural perspectives. Only a small subset of studies named theoretical frameworks directly, and even fewer used theory to guide program design or analysis. Nevertheless, the practices described across studies reflect mechanisms consistent with Situated Learning Theory, Communities of Practice, and Social Cognitive Theory. Students learned through observing more experienced peers, interacting during shared tasks, and gradually increasing their participation within engineering communities. Reflection, however, was rarely structured intentionally for mentees and was more commonly discussed as part of mentors' developmental experiences [7], [27].

The findings suggest that peer mentoring in makerspaces, design studios, and project-based learning environments functions as a relational and participatory instructional practice, even when not formally conceptualized as such. While engagement and belonging are commonly reported outcomes, identity development remains underexplored, particularly for first-year students. Additionally, the lack of consistent mentor preparation and limited theoretical grounding point to opportunities for more intentional design and study of peer mentoring structures in early engineering education.

## Conclusion

This scoping literature review synthesized 17 studies examining peer mentoring in makerspaces, design studios, and project-based learning environments within undergraduate engineering education. Across the literature, peer mentoring consistently appeared as an embedded instructional practice within hands-on learning contexts, most commonly in first-year design courses and shared making spaces. Peer mentors were typically near-peers who had prior experience with the course or environment and supported students during design, fabrication, and collaborative problem-solving activities.

Engagement was the most consistently reported outcome across studies, reflected in increased participation, help-seeking behaviors, and sustained involvement in learning activities. Several studies also described improvements in students' sense of belonging, particularly when peer mentors were visible, approachable, and integrated into the learning environment. In contrast, explicit examination of engineering identity development among first-year students was limited. When identity was discussed, it was more often framed around mentors' own professional growth rather than mentees' identity formation.

Although few studies explicitly named learning theories, the mentoring practices described aligned conceptually with sociocultural perspectives of learning. Students learned through participation in authentic engineering activities, observation of more experienced peers, and interaction within shared learning spaces. Reflection, however, was rarely structured for mentees and was more commonly discussed as part of mentors' developmental experiences. Taken together, the findings suggest that peer mentoring functions as a relational and participatory instructional strategy in hands-on engineering environments, but its learning mechanisms and outcomes are not yet examined with consistent theoretical or methodological rigor.

Building on these findings, the next phase of this work will further examine peer mentoring as an instructional practice within first-year engineering learning environments. In particular, future work will focus on better understanding how peer mentoring supports mentor development and learning processes in hands-on contexts. This direction aims to address the current lack of theoretical grounding in the literature and contribute a more structured understanding of how peer mentoring functions within early engineering education.

**Limitations**

This review is limited by its reliance on ERIC and ASEE PEER and by the predominance of conference-based studies, many of which emphasized program description over theory-driven analysis or longitudinal outcomes. In addition, there was substantial variability in how peer mentoring roles were defined, titled, and prepared, making cross-study comparison challenging.

A limitation of the reviewed literature is the minimal attention to gender beyond basic demographic reporting. Although several studies included gender as contextual information, none examined how peer mentoring interacts with gendered dynamics of participation or belonging within makerspaces or design environments, making it a future opportunity to study.

Additional opportunities for future work include clearer articulation of mentoring roles, more intentional mentor preparation models, and explicit integration of learning theory into mentoring design. Longitudinal studies that examine how engagement, belonging, and identity develop over time in peer-mentored environments would further strengthen understanding of peer mentoring as an instructional practice in early engineering education.

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