Bridging Gaps in Engineering Teamwork: A Literature Review through the Lens of Cultural-Historical Activity Theory (CHAT)

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Abstract

Teamwork is a core competency in engineering education, yet persistent challenges remain in cultivating collaboration that prepares graduates for professional practice. This study reports a systematic literature review (SLR) of 22 peer-reviewed studies (2010–2024) examining how Cultural-Historical Activity Theory (CHAT) can be applied to understand and strengthen teamwork development in engineering programmes. Guided by PRISMA 2020 procedures, the review identifies recurrent contradictions between intended learning outcomes and prevailing educational practices, particularly regarding assessment design, role distribution, and inclusivity. Five thematic clusters emerged: assessment misalignment, role clarity and flexibility, technology as mediator, diversity and inclusion, and instructor facilitation, each mapped to CHAT components to illustrate systemic influences on teamwork learning. The synthesis highlights that while project-based and blended learning environments show promise, contradictions persist when institutional rules and assessment reward individual performance over collective achievement. The findings contribute to a clearer picture of how CHAT can structure evidence-based interventions to align curriculum, pedagogy, and assessment with teamwork objectives. The paper concludes by outlining practical implications for curriculum redesign, faculty development, and equitable assessment reform, positioning CHAT as a valuable framework for building teamwork competence in engineering education.

Keywords: Teamwork Competencies, Engineering Education, Cultural-Historical Activity Theory, Collaborative Learning, Curriculum Design

1 Introduction

Teamwork has become an indispensable competency in engineering education, reflecting the increasing demand for graduates who can operate effectively in interdisciplinary and multicultural professional environments (Sekhar et al., 2023; Kropp, 2024; Hutson et al., 2025). While industry stakeholders consistently highlight collaboration as essential for solving complex problems (Case School of Engineering, 2023), higher education institutions continue to struggle with designing and assessing learning experiences that intentionally cultivate teamwork skills (Goldsmith et al., 2024; Burgess et al., 2023).

Research indicates that engineering students often face challenges in team settings, including communication barriers, unequal participation, and cultural or gendered differences that undermine group effectiveness (Belanger et al., 2022; Zhang et al., 2024). Post-pandemic transitions to hybrid and online learning environments have further complicated these dynamics, requiring new strategies to integrate technology, equity, and flexibility into collaborative learning (Okoye Ifeanyi, 2023; Burr, 2025; Darby, 2025). Addressing these challenges requires more than ad-hoc adjustments; it calls for a systemic lens that connects individual behaviours, community norms, institutional rules, and cultural contexts.

Cultural-Historical Activity Theory (CHAT), as advanced by Engeström (1987), provides such a lens by conceptualising learning as a mediated activity shaped by tools, rules, division of labour, and community engagement. CHAT foregrounds systemic contradictions, such as when assessment practices reward individual achievement while curricula promote teamwork, which are particularly relevant to engineering education (Mentz & de Beer, 2021; Núñez, 2021).

This study applies CHAT to a systematic literature review (SLR) of 22 empirical studies on teamwork in engineering education. The objectives are threefold: (a) to synthesise how teamwork has been

conceptualised and studied in engineering education, (b) to map emergent findings onto CHAT components to reveal systemic enablers and tensions, and (c) to identify pedagogical strategies for more inclusive and effective teamwork instruction. By distinguishing between theoretical framing and empirical synthesis, the paper contributes a clearer account of teamwork challenges and provides evidence-based recommendations for curriculum and assessment design.

2 Literature Review

Teamwork has long been recognised as a central outcome of engineering education, with accreditation bodies such as ABET and the Washington Accord emphasising collaborative competence as a key graduate attribute (International Engineering Alliance, 2021; ABET, 2023). Despite this recognition, systematic evidence indicates that teamwork is often treated as an implicit by-product of project-based learning (PBL) rather than as an intentionally designed and assessed outcome (Burgess et al., 2023; Goldsmith et al., 2024).

2.1 Teamwork in Engineering Education

Studies consistently highlight the gap between the importance of teamwork in professional practice and the limited strategies available to foster it in curricula (Sekhar et al., 2023; Kropp, 2024). Engineering students frequently report challenges related to role ambiguity, uneven workload distribution, and interpersonal conflict (Belanger et al., 2022). While collaborative projects provide opportunities to engage in authentic teamwork, without explicit scaffolding, students often reproduce inequitable participation patterns (Oberprieler, 2019; Garcia & Treude, 2025).

2.2 Assessment and Institutional Practices

A recurring barrier lies in assessment practices. Traditional grading schemes frequently privilege individual performance, creating contradictions between what is taught (teamwork as a goal) and what is rewarded (individual output). Such misalignments reduce motivation for collaboration and can exacerbate tensions among students (Karlovsek & Ruiz, 2020; Ryan & Deci, 2020). Alternative approaches, such as peer assessment or group contracts, have been explored, yet their implementation remains inconsistent across institutions (Okoye Ifeanyi, 2023).

2.3 Technology and Teamwork in Contemporary Contexts

The increasing use of digital platforms has reshaped collaborative practices, particularly in hybrid and online learning contexts. Tools such as learning management systems, shared documents, and communication platforms have the potential to strengthen teamwork, but studies show that unequal access and variable digital literacy often create new challenges (Lo & Hew, 2019; Divis et al., 2022). These findings underscore the importance of examining how technology mediates collaboration rather than assuming it will inherently improve outcomes.

2.4 Equity, Diversity and Inclusion

Issues of equity and inclusion also shape teamwork in engineering education. Research demonstrates that gender, cultural background, and language proficiency significantly influence participation and leadership within teams (Zhang et al., 2024; Garcia & Treude, 2025). Without deliberate facilitation, these dynamics risk

reproducing systemic inequities rather than promoting inclusive collaboration (Koh et al., 2016; Marra et al., 2016).

2.5 Gaps in the Literature

Although the literature provides valuable insights into barriers and opportunities for teamwork instruction, most studies approach the issue in a fragmented way, focusing on isolated interventions or single institutional contexts. Few reviews have systematically synthesised this body of work, and even fewer have analysed teamwork development through a systemic theoretical framework capable of explaining underlying contradictions across contexts. This gap highlights the need for an integrative approach that can both synthesise existing evidence and guide practical strategies for curriculum and assessment reform.

3 Theoretical and Conceptual Framework

3.1 Cultural-Historical Activity Theory (CHAT)

Cultural-Historical Activity Theory (CHAT) provides a systemic perspective for examining human activity, highlighting how individual actions are shaped by tools, rules, community expectations, and the division of labour (Engeström, 1987; Vygotsky, 1978). Building on socio-cultural traditions, CHAT conceptualises learning as the outcome of dynamic interactions within activity systems rather than as an isolated cognitive process (Cole & Engeström, 1993).

3.2 Key Constructs

An activity system in CHAT consists of six interacting components: subject, object, mediating tools, rules, community, and division of labour, all of which collectively shape the activity outcome. Contradictions within or between these components are viewed not as failures but as opportunities for transformation and learning (Engeström, 2001). For example, tensions between assessment rules that privilege individual performance and teamwork-focused curricular goals can reveal structural misalignments that undermine collaboration.

3.3 CHAT and Teamwork in Engineering Education

In the context of engineering education, CHAT has been increasingly recognised as a useful framework for unpacking the systemic nature of teamwork development (Mentz & de Beer, 2021; Núñez, 2021). By situating teamwork as an activity system, CHAT allows researchers and educators to identify where contradictions emerge, whether in role distribution, assessment practices, or access to collaborative technologies and how these tensions shape students' learning experiences.

3.4 Conceptual Framework for this Study

This paper adopts CHAT as the guiding framework for analysing and synthesising findings from 22 studies of teamwork in engineering education. Figure 1 illustrates the conceptual model, mapping teamwork competencies against CHAT components to highlight how systemic elements interact in shaping teamwork preparedness. The framework was used to guide data coding and synthesis in the systematic review.

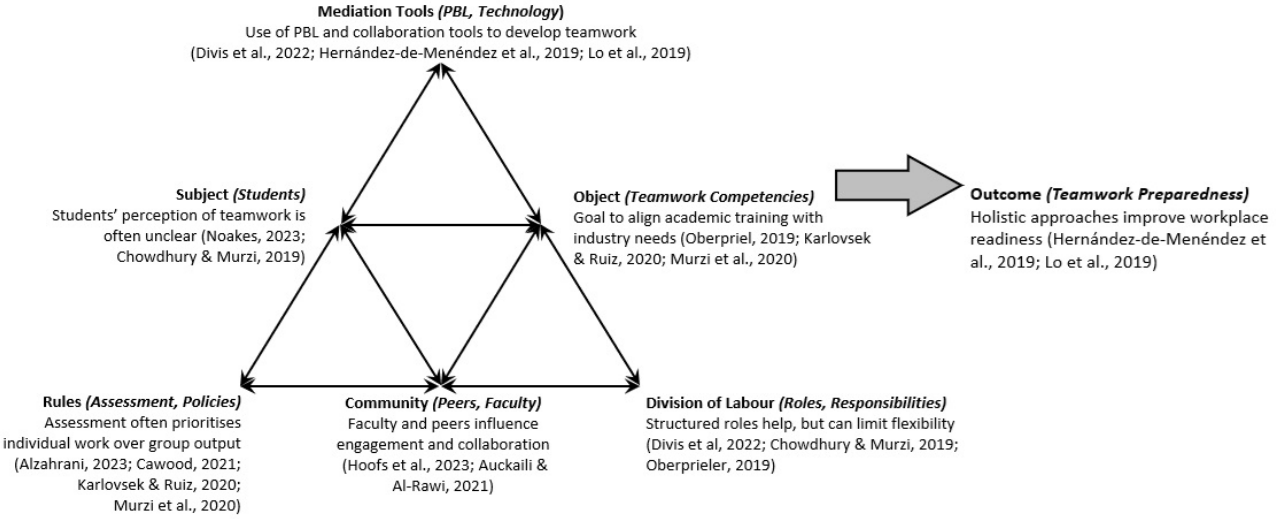

Figure 1: CHAT model applied to teamwork competencies (Adapted from Engeström, 1987 and Cole & Engeström, 1993, with application to teamwork in engineering education)

It is essential to note that Figure 1 illustrates the conceptual framework of this study. The empirical findings derived from the systematic review are presented separately in Section 5. This distinction ensures that theoretical grounding and evidence synthesis remain clearly delineated, thereby addressing common challenges in literature reviews where conceptual and empirical elements overlap.

4 Methodology

4.1 Research Design

This study employed a systematic literature review (SLR) to synthesise evidence on how teamwork is intentionally taught and assessed in engineering education. The review was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) framework, ensuring transparency in search, screening, and synthesis procedures (Page et al., 2021). CHAT served as the analytical lens for coding and interpretation, but was applied only after eligible studies were identified.

4.2 Search Strategy

Electronic databases, including Scopus, Web of Science, ERIC, and IEEE Xplore, were searched for peer-reviewed publications between 2010 and 2024. Search strings combined keywords such as teamwork, engineering education, project-based learning, and Cultural-Historical Activity Theory. The reference lists of selected articles were also screened to identify additional relevant studies.

4.3 Inclusion and Exclusion Criteria

Studies were included if they:

- Focused on teamwork or collaborative learning in higher engineering education,
- Reported empirical findings, and
- Addressed learning design, pedagogy, or assessment.

Studies were excluded if they:

- Did not focus on engineering education,
- Lacked a connection to teamwork or collaborative competence, or
- Provided only a conceptual discussion without empirical evidence.

4.4 Screening Process

The initial search identified 88 records. After removing eight duplicates, 80 records remained for abstract and title screening. Forty-two were excluded for not meeting the inclusion criteria. Full texts of 38 studies were then assessed for eligibility, resulting in the exclusion of 16 papers: five that were not related to engineering education, five that lacked any CHAT relevance, and six that had insufficient empirical data. This process yielded a final corpus of 22 studies. The screening process is summarised in Figure 2.

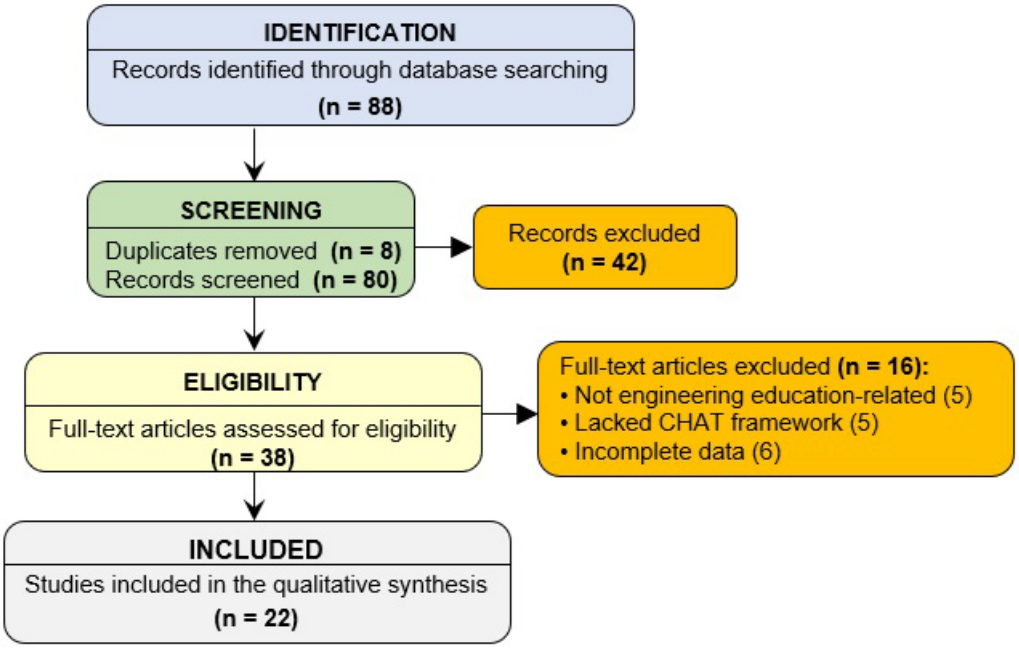

Figure 2: PRISMA 2020 flow diagram of study selection (Adapted from Page et al., 2021)

4.5 Data Extraction and Analysis

Data were extracted systematically using a coding matrix that captured publication details, research design, context, teamwork interventions, and outcomes. CHAT components, subject, object, mediating tools, rules, community, and division of labour were used to guide thematic coding. Two researchers independently reviewed each study, and discrepancies in coding were resolved through discussion until consensus was reached.

4.6 Synthesis Approach

The analysis proceeded in two stages. First, descriptive mapping provided an overview of study characteristics. Second, thematic synthesis clustered findings across studies into recurring patterns aligned with CHAT components. This approach enabled both an empirical account of teamwork practices and a theoretically informed interpretation of systemic tensions. The results of this synthesis are presented in Section 5.

5 Results and Discussion

This section presents the findings of the systematic review of 22 studies on teamwork in engineering education, organised into five thematic clusters. The analysis was guided by CHAT, which provided a lens for identifying how systemic elements, rules, tools, division of labour, community, and subject-object relations shaped teamwork practices. The aim is to demonstrate not only what the studies reported but also how their findings collectively reveal systemic contradictions and opportunities for improving teamwork instruction.

5.1 Overview of the Corpus

The 22 studies spanned a range of geographical contexts, including North America, Europe, Asia, and Africa, and covered both undergraduate and postgraduate levels. Research designs included case studies, surveys, quasi-experiments, and mixed-method approaches. Most studies were situated in project-based or problem-based learning environments, reflecting the dominant pedagogical strategy for embedding teamwork in engineering curricula.

5.2 Thematic Synthesis

Across the corpus, five major themes emerged: assessment misalignment, role clarity and flexibility, technology as mediator, diversity and inclusion, and instructor facilitation. These themes are summarised in Table 1, which maps them to CHAT components and illustrates their systemic significance.

Table 1: Synthesis of 22 studies mapping teamwork to themes to CHAT components (Developed by the authors, based on thematic synthesis of the 22 included studies)

Theme (from 22 studies)	CHAT Component(s)	Key Findings	Example Studies
Assessment misalignment	Rules, Object	Individual-focused grading discouraged collaboration and created tensions.	Ryan & Deci (2020); Karlovsek & Ruiz (2020)
Role clarity and flexibility	Division of Labour, Community	Structured roles supported teamwork but often limited adaptability and innovation.	Chowdhury & Murzi (2019); Oberprieler (2019)
Technology as mediator	Tools	Collaboration platforms enhanced communication, though unequal access remained a barrier.	Lo & Hew, 2019; Divis et al. (2022)

Theme (from 22 studies)	CHAT Component(s)	Key Findings	Example Studies
Diversity & inclusion	Subject, Community	Gender and cultural differences significantly shaped patterns of engagement.	Zhang et al. (2024); Garcia & Treude (2025)
Instructor facilitation	Rules, Community	Faculty scaffolding was critical for sustained teamwork skill development.	Koh et al. (2016); Marra et al. (2016)

5.3 Theme 1: Assessment Misalignment

A recurring contradiction concerned assessment practices that emphasised individual achievement, while teamwork was presented as a core outcome. Studies have reported that when grades are primarily allocated based on individual contributions, students are less motivated to engage meaningfully in teamwork (Karlovsek & Ruiz, 2020; Ryan & Deci, 2020). Within CHAT, this tension reflects misalignment between the rules (grading criteria) and the objective (teamwork development). Addressing this contradiction requires assessment systems that reward both individual accountability and collective performance.

5.4 Theme 2: Role Clarity and Flexibility

Several studies emphasised the importance of clearly defined roles in supporting effective teamwork (Chowdhury & Murzi, 2019; Oberprieler, 2019). Structured role allocation helped distribute workload and supported accountability. However, rigid roles sometimes constrain adaptability and creativity, leading to frustration among students. In CHAT terms, this tension lies within the division of labour and its interaction with the community. Effective teamwork pedagogy must therefore balance structured role clarity with opportunities for role negotiation and rotation.

5.5 Theme 3: Technology as Mediator

The increasing integration of digital tools was found to mediate teamwork in both positive and problematic ways. On one hand, platforms such as shared documents, virtual workspaces, and messaging systems enhanced communication and coordination (Lo & Hew, 2019; Divis et al., 2022). On the other hand, unequal access to technology and varying levels of digital competence created new forms of exclusion. From a CHAT perspective, this highlights the mediating role of tools, which both enable and constrain teamwork depending on their accessibility and integration into learning design.

5.6 Theme 4: Diversity and Inclusion

Team composition significantly shaped teamwork experiences, particularly regarding gender and cultural diversity. Studies reported that while diverse teams brought richer perspectives, they also faced challenges such as unequal participation and implicit bias (Zhang et al., 2024; Garcia & Treude, 2025). These dynamics are situated within the subject and community components of CHAT, illustrating how social identities influence interaction within activity systems. Inclusive teamwork instruction requires proactive facilitation to ensure equitable participation and recognition of contributions.

5.7 Theme 5: Instruction Facilitator

Finally, instructor involvement emerged as a critical factor in sustaining teamwork development. Faculty who actively scaffolded teamwork processes through feedback, coaching, or structured reflection helped students develop collaboration skills more effectively (Koh et al., 2016; Marra et al., 2016). In CHAT terms, instructors act as part of the community while also shaping the rules that govern interaction. Effective facilitation transforms contradictions into learning opportunities, reinforcing the value of teamwork as a central educational outcome.

5.8 Discussion of Findings

Taken together, these themes underscore the systemic nature of teamwork instruction. CHAT proved useful in highlighting contradictions, such as the gap between teamwork goals and assessment rules, which recur across diverse contexts. Unlike prior narrative reviews, this synthesis contributes a structured mapping of teamwork practices to CHAT components, offering a clearer account of where interventions are most needed.

The findings suggest that engineering programmes must adopt integrated strategies: aligning assessment with teamwork objectives, balancing role clarity with flexibility, ensuring equitable access to digital tools, addressing diversity proactively, and strengthening faculty capacity for facilitation. By making these systemic contradictions explicit, the review provides a foundation for evidence-based curriculum redesign that foregrounds teamwork as both a learning process and an assessable outcome.

6 Implications

The synthesis of 22 studies through the lens of CHAT provides a structured understanding of teamwork in engineering education that extends beyond fragmented findings in individual studies. By highlighting recurring contradictions between curricular intentions and institutional practices, the review identifies targeted opportunities for both educators and researchers.

6.1 Implications for Practice

For practitioners, the findings emphasise the importance of aligning curricular design, pedagogy, and assessment to create coherent support for teamwork development. Specifically:

- Assessment reform is essential. Group assessments should strike a balance between individual accountability and recognition of collective achievement to avoid undermining collaboration (Karlovsek & Ruiz, 2020; Ryan & Deci, 2020).
- Role scaffolding should be intentionally designed. Structured role allocation can help distribute responsibilities, but it should also allow for flexibility in negotiation and adaptation (Chowdhury & Murzi, 2019).
- Inclusive facilitation is critical. Instructors must proactively address equity issues to ensure that diverse student populations are supported, particularly in multicultural and multilingual contexts (Zhang et al., 2024).
- Technology integration must be strategic. Digital platforms should be accompanied by guidance and equitable access measures to prevent new forms of exclusion (Divis et al., 2022).

6.2 Implications for Research

For researchers, the review highlights the potential of CHAT as both an analytical and design tool. Future studies should:

- Move beyond descriptive accounts by systematically examining contradictions in teamwork pedagogy across contexts.
- Investigate assessment innovations that operationalise teamwork learning outcomes without defaulting to individualised grading.
- Explore equity and inclusion more explicitly, examining how systemic factors shape diverse students' teamwork experiences.
- Develop longitudinal studies to track how teamwork competencies evolve across curricula and into professional practice.
- Together, these implications underscore the value of CHAT not only as a theoretical lens but also as a practical framework for guiding evidence-informed interventions.

7 Conclusion

This study synthesised 22 empirical investigations of teamwork in engineering education through the lens of Cultural-Historical Activity Theory (CHAT). The analysis identified five recurrent themes: assessment misalignment, role clarity and flexibility, technology as mediator, diversity and inclusion, and instructor facilitation, each mapped to CHAT components to reveal systemic enablers and tensions.

Unlike prior narrative accounts of teamwork pedagogy, this review offers a structured, theory-informed synthesis that makes visible the contradictions undermining teamwork development. By distinguishing clearly between conceptual framing and empirical findings, the paper contributes both methodological clarity and substantive insights.

The key contribution of this study lies in demonstrating how CHAT can structure evidence across contexts to highlight leverage points for change in engineering curricula. In particular, it shows that contradictions far from being obstacles can serve as opportunities for designing more intentional teamwork instruction. The findings have direct implications for aligning assessment, supporting inclusive practices, and strengthening faculty facilitation, while also pointing to new directions for systematic research.

By reframing teamwork as a systemic activity rather than an isolated skill, this study advances understanding of how engineering education can more effectively prepare graduates for collaborative professional practice.

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