Towards a Unified Group Scaffolding Framework: Insights From MGTAs

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Supporting students' collaborative work requires more than simply placing them in groups; instructors must actively shape participation and discourse through scaffolding. Group scaffolding refers to the set of instructional strategies that help students coordinate, distribute responsibility, and build shared understanding in groups. Despite its relevance for undergraduate active learning environments, existing theories have tended to isolate central elements, including teacher guidance of student reasoning, discourse moves shaping participation, and classroom norms structuring collaboration. In this paper, we analyze episodes of instruction by mathematics graduate teaching assistants (MGTAs) to motivate a unified theory of group scaffolding. Our framework integrates four interdependent dimensions: (a) norms setting, (b) task and material design, (c) discourse moves, and (d) access distribution. We argue that this theory both advances research on collaborative learning in undergraduate mathematics and informs professional development efforts that prepare instructors to foster more equitable and effective group work.

Keywords: Group Scaffolding, Active Learning, Discourse Moves, Norm Setting

Active learning has been used to characterize student-centered instructional approaches focused on heightened engagement with mathematics through structured activities (Doolittle et al., 2023). The implementation of these approaches in undergraduate mathematics initially centered on gateway courses, but it has also expanded to upper-division courses, including linear algebra, geometry, and logic (Theobald et al., 2020). This widespread adoption implies that mathematics graduate teaching assistants (MGTAs) are now frequently required to implement these pedagogical strategies.

Typically, classroom activities in these courses are often designed as problem-solving and discussions in group settings, allowing students to investigate, communicate, and reflect together while receiving feedback from peers and instructors (Laursen & Rasmussen, 2019). Yet, mathematical discussions in groups are dynamic, constantly influenced by a number of socio-cognitive and instructional factors that could create unequal conditions for students to achieve similar learning goals. Esmonde (2009), for instance, examined cooperative structures and found that students often assumed roles such as "expert," "novice," or "facilitator," with experts dominating quiz settings while facilitator roles promoted more equitable participation. Moreover, Reinholz and Johnson (2022) provided compelling evidence that active learning, when implemented without additional instructional support for cooperative learning, can lead to performance gaps across certain student groups.

Effective instructional practices require more than simply grouping students; structured approaches, including rotating roles, designing open-ended tasks, and framing explicit group norms, can help to distribute authority and promote deeper engagement among groups (Cohen & Lotan, 2014; Esmonde, 2009; Laursen & Rasmussen, 2019). Furthermore, other strategies such as circulating to pose probing questions, monitoring participation patterns, and amplifying marginalized voices could foster both collaborative learning and sense of belonging (Kogan & Laursen, 2014; Reinholz & Shah, 2018).

While some of these practices are typically associated with the well-established notion of scaffolding—the instructional support provided by a more knowledgeable other to help learners progress beyond their independent capabilities (Wood et al., 1976), active learning settings require attention to group scaffolding. Unlike traditional scaffolding, which targets individual learners, group scaffolding refers to strategies that support the collective participation, discourse, and problem-solving of the group as a whole (Webb et al., 2025).

Some theories have identified overarching elements involved in group scaffolding, including discourse moves that shape participation (Chapin et al., 2009) and classroom norms that structure access to collaboration (Yackel & Cobb, 1996). These elements, however, have largely been treated in isolation, suggesting the need for a more cohesive framework that integrates these perspectives into a unified account.

The purpose of this report is twofold. First, we explore the possibility of a general framework for group scaffolding in undergraduate mathematics, drawing on instances of novice instructors coordinating collaborative activities in active learning classrooms. Although some studies have reported difficulties experienced by novice instructors in using group scaffolding (Winter et al., 2002), their experiences provide contrasting cases that highlight the affordances and limitations of group scaffolding in practice. Second, we consider how this framework can inform the design of professional learning opportunities for novice instructors. Research has shown that MGTAs often default to individualistic instructional practices, downplaying student-to-student interaction (Winter et al., 2002), and may prioritize procedural efficiency over conceptual learning, offering prescriptive guidance with little time for reflection ([Reference removed for blind review]). Our central research question is: how can a detailed analysis of group scaffolding in periods of MGTAs instruction reveal the critical elements required for a comprehensive theory?

Conceptual Framework

Scaffolding was first introduced by Wood et al. (1976) to describe the process by which a more knowledgeable other supports a learner's progress beyond what they could accomplish independently. Grounded in Vygotsky's (1978) theory of the Zone of Proximal Development, scaffolding involves providing temporary, adaptive support—such as prompting, modeling, or structuring tasks—that enables learners to engage in more sophisticated reasoning. As students gain competence, this support is gradually withdrawn, fostering independence and deeper understanding. Traditionally, scaffolding has been conceptualized as a one-on-one interaction between teacher and learner.

In student-centered environments, however, learning often occurs in small groups where students engage collectively in problem-solving and discussion. In these contexts, instructors need to carefully attend to the dynamics of group participation, shared reasoning, and broad access to mathematical ideas. Group scaffolding refers to instructional moves, task designs, and resources that deliberately support the group as a collective—facilitating broad participation, encouraging explanation and justification, and helping students build on one another's contributions. Unlike individual scaffolding, which centers on the dyadic relationship between teacher and student, group scaffolding emphasizes how instructors shape the social and cognitive ecology of collaborative work.

Although active learning reforms in undergraduate mathematics have increased the use of group work, research suggests that group scaffolding remains underutilized, especially among novice instructors such as MGTAs (Reinholz & Shah, 2018; Winter et al., 2002). Moreover, the use of group scaffolding has often been found to be incomplete, leading in some cases to students defaulting to unequal roles, limited participation, and superficial task completion.

Research on scaffolding group work identifies a number of strategies that could support broad collaboration. Assigning roles and setting group norms clarifies expectations and fosters equitable engagement (Cohen & Lotan, 2014; Esmonde, 2009; Horn, 2012), while structured tasks and discourse moves coordinate problem-solving and promote peer-to-peer discourse (Boaler, 2008; Chapin et al., 2009; Lotan, 2003). Reflection, self-assessment, and journaling encourage metacognition and shared responsibility (Bielaczyc & Collins, 1999; Gillies, 2016), and instructor facilitation and visual representations provide just-in-time support and anchor joint understanding (Cobb et al., 1997; Roschelle & Teasley, 1995).

Three studies have attempted to identify the most essential elements involved in group scaffolding. First, Wood et al. (1976) focused on teacher-to-student interactions, suggesting that effective scaffolding involves breaking tasks into manageable steps, maintaining student engagement, and transferring responsibility to learners (fading). This perspective highlights the teacher's role in providing just enough structure to support students' problem-solving without taking over the process entirely. Although it is not discussed by these authors, the two initial phases of this process are closely connected to instructors' learning goals. While breaking a procedural problem into more manageable steps and maintaining engagement, instructors can ask students to justify each step, providing opportunities for students to deepen their conceptual understanding.

While this framework focuses on the interactions between teachers and individual students, Calor et al. (2022, 2024) extended these ideas at the group level identifying three principles: diagnosis, contingency, and fading. Group scaffolding is a process that requires an initial assessment of the group collaboration (diagnosis), after this assessment, support is adapted to the specific needs of the group at that moment (contingency), and then support is gradually removed as the group becomes more independent, shifting the responsibility for learning back to the students in the group (fading).

Chapin et al. (2009) emphasized the role of discourse moves in shaping participation during mathematical discussions. Their framework identifies specific teacher discourse moves, such as revoicing, asking students to restate or expand on peers' contributions, and pressing for reasoning, that can sustain dialogue and promote deeper engagement with mathematical ideas. These strategies not only support individual student reasoning but also serve as group scaffolds by making ideas public, encouraging broader participation, and fostering a collective sense of inquiry. The focus on discourse highlights that scaffolding is not limited to structuring tasks but also emphasizes the role instructors play in mediating talk to create wider opportunities for collaboration.

A third perspective comes from Yackel and Cobb (1996), who theorized the role of classroom norms in shaping how students access and engage in collaborative mathematics. They distinguished between sociomathematical norms—taken-as-shared understandings of what counts as a valid mathematical explanation or justification—and more general interactional norms, such as expectations for listening to and responding to peers. From this perspective, scaffolding is inseparable from the broader social and normative structures that govern participation in a classroom. Instructors contribute to scaffolding not only through immediate interventions but also by setting norms that could enable or constrain collaboration. This framework underscores that effective group scaffolding must be understood in relation to the classroom's ecology of participation, rather than as a series of isolated teacher actions.

Methodology

This paper is best understood as a conceptual study with empirical grounding. Our aim is to theorize group scaffolding in undergraduate mathematics instruction by bringing together existing strands of research (e.g., scaffolding, classroom norms, talk moves, task design, access to opportunties to learn) into a unified framework. To motivate and situate this theorizing, we draw on a small set of illustrative episodes collected in the context of a professional development program for MGTAs. The episodes were drawn from classroom observations of MGTAs in undergraduate mathematics courses. Although MGTAs were relatively new to teaching, they all participated in a professional learning opportunity intended to provide opportunities for them to reflect on a number of instructional issues related to students' participation in the classroom, including classroom norms, students' identity, and discourse moves. We selected four short episodes that highlight variation in how instructors attempted to scaffold group work. These episodes were not chosen to be representative but to serve as eliciting cases (Flyvbjerg, 2006) that reveal different dimensions of scaffolding—norm-setting, task design, use of tools, feedback practices, and participation. We analyzed each episode through iterative discussions, asking: What forms of scaffolding are visible here (structural, discursive, participatory)? What is missing or underdeveloped? How does this episode help identify the critical components of a unified theory of group scaffolding? The methodology follows a theory-building through exemplars approach (diSessa & Cobb, 2004), in which empirical material is used to motivate and refine conceptual categories.

Conceptual Framework

Four episodes were selected to inform a unified framework of group scaffolding, representing contrasting cases of different aspects of group scaffolding. Each episode is accompanied by a brief analytic commentary. Rather than reporting outcomes (e.g., student learning), we focus on how each episode illustrates different approaches to scaffolding group work and what those approaches reveal about potential dimensions present in a unified theory.

Episode 1: Group Work at the Board. An MGTA asked students to work on the whiteboard in groups, restricting each group to a single marker. This design choice created a structural scaffold for participation by requiring shared control of a resource. The establishment of explicit norms or facilitation moves, however, was not clear, which could prompted a dynamic in which some students dominated the discussion and others were marginalized from it. This episode illustrates the importance of material tools as scaffolds but also the limits of tool-based scaffolding in the absence of norms and discourse supports.

Episode 2: Optional Group Work. Another MGTA invited students to work in groups but framed group work as an option. Consistently, when several students chose to work individually, the MGTA did not encourage further collaboration but attempted to monitor each student's work, visibly increasing the demands to attend to individual needs. Here, the absence of norm-setting undermined the possibility of collaboration. The episode shows how scaffolding is not just about offering opportunities for collaboration but about structuring access so that participation is expected and supported.

Episode 3: Prescriptive Group Monitoring. In a different class, an MGTA required students to work in groups and regularly circulated among them to monitor their progress. However, the instructor's feedback was mainly prescriptive, telling students what to do rather than prompting them to reason collaboratively. This scaffolding emphasized teacher authority rather than group autonomy, showing how certain forms of monitoring can unintentionally reduce opportunities for decentering authority and promoting student-to-student discourse.

Episode 4: Inquiry-Oriented Group Monitoring. Finally, an instructor also required group work but engaged in monitoring that was inquiry-based, using open-ended questions and encouraging all members to contribute. This episode reflects a more integrated enactment of group scaffolding: task structure, norms of inclusion, and talk moves worked together to promote collaborative reasoning. However, even here, isolated moments of uneven participation persisted. It is possible that this uneven participation could have faded in subsequent classes, but it could also suggest a need for other types of other group scaffolding strategies (e.g., role assignments, status interventions).

These episodes show a spectrum of developing scaffolding practices: from structural-only (Episode 1), to secondary (Episode 2), to prescriptive (Episode 3), to more fully integrated (Episode 4). An overall analysis of these episodes highlights the following central dimensions of group scaffolding closely interconnected: Norms setting (e.g., whether group work is required, how roles are structured, how ideas should be shared), task and material design (e.g., open-ended problems, tools like markers to regulate access), discourse moves (e.g., prescriptive vs. inquiry-based feedback, individual vs group questioning), and access distribution (whether the participation of each peers in a group is supported). These results lay the groundwork for our proposed unified theory of group scaffolding.

Toward a Unified Theory of Group Scaffolding

The analysis presented above reveals both the affordances and limitations of MGTAs' attempts to coordinate group work. Together, they illustrate the existence of multiple dimensions associated with group scaffolding instead of isolated elements previously identified in the literature–task design, discourse moves, or classroom norms. Effective group scaffolding emerges through the interaction of these elements that jointly support broad participation in mathematical reasoning. Drawing from prior theories (Chapin et al., 2009; Wood et al., 1976; Yackel & Cobb, 1996) and extending them through the analysis of our episodes, we propose a unified theory of group scaffolding that integrates four interdependent dimensions illustrated in Figure 1. The following is a brief description of each of these elements.

Norms and Expectations. Group scaffolding requires the establishment of clear expectations for participation, including both general interactional norms (e.g., listening to peers, giving space to contribute ideas) and sociomathematical norms (e.g., what counts as a valid explanation). As Episode 2 illustrated, in the absence of such norms, group work may fail to materialize altogether.

Task and Material Design. The design of mathematical tasks and the structuring of material tools shape opportunities for collaboration. The one-marker activity in Episode 1 demonstrates how material resources can serve as structural scaffolds, channeling participation toward collective work. Yet, without accompanying discourse supports, such tools may also reinforce uneven participation.

Discourse Moves. Instructor talk is central to sustaining collaboration. Prescriptive feedback, as seen in Episode 3, may reduce opportunities for students to engage with each other's reasoning. In contrast, inquiry-oriented talk moves (Chapin et al., 2009), such as revoicing and pressing for justification, can prompt groups to develop shared understandings and sustain mathematical dialogue.

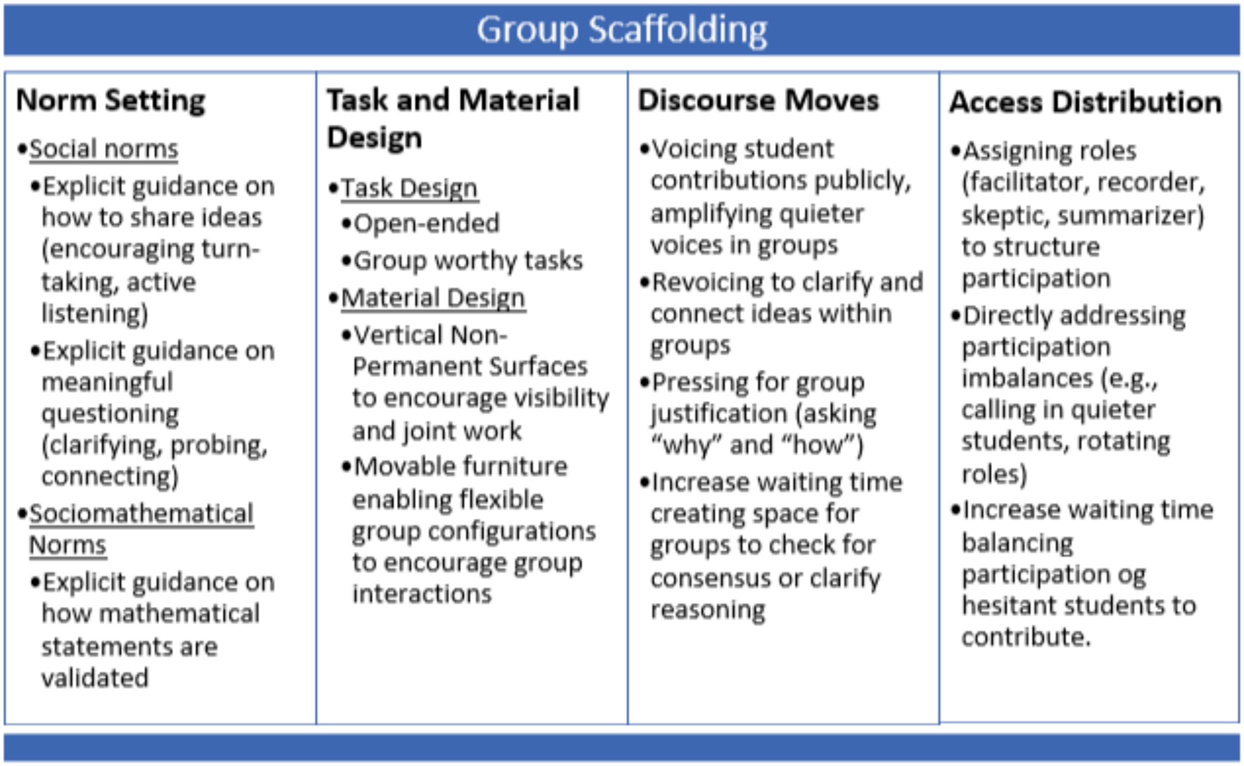

Figure 1. Central Dimensions of Group Scaffolding

Access Distribution. A comprehensive theory must also account for how scaffolding practices distribute opportunities to learn (Esmonde, 2009) across all group members, widening access to mathematical content, discourse, and positionalities to all students. As Episode 4 showed, even when inquiry-based scaffolding is present, participation may remain uneven, presenting obstacles to collaborative learning. Mediation strategies, such as assigning roles (Cohen & Lotan, 1997) or directly addressing participation imbalances (Esmonde, 2009), are necessary to ensure that scaffolding supports the learning of all students, not just the most vocal.

We argue that group scaffolding can be conceptualized as the dynamic coordination of these four dimensions, with instructors navigating among them in response to student activity. Rather than a checklist of strategies, the framework positions scaffolding as a relational and situated practice that integrates structural, discursive, normative, and broad supports. This unified perspective provides a basis for analyzing classroom practice and designing professional development that makes visible the complex work of orchestrating group learning in undergraduate mathematics.

Toward a Unified Theory of Group Scaffolding

This unified theory of group scaffolding proposed here has direct implications for the design of professional development (PD) for novice instructors. Traditional PD often emphasizes either structural strategies, such as assigning roles, or general encouragement of active learning without fully addressing how norms, discourse moves, tools, and equity interact in practice. By contrast, our framework suggests that PD should make these dimensions explicit and help instructors learn to coordinate them in response to classroom dynamics. One promising approach is the use of video-based reflection, where novice instructors analyze episodes of classroom practice—both their own and others'—through the lens of the four scaffolding dimensions. Such an approach not only highlights the complexity of group orchestration but also makes visible the affordances and limitations of different scaffolding strategies.

In addition, PD should provide practice-based repeated opportunities for instructors to rehearse and refine scaffolding moves. For example, role-playing activities can allow instructors to practice inquiry-oriented monitoring and equity-promoting talk moves in a low-stakes environment, while structured debriefs can help them connect these practices back to the broader framework. Importantly, PD must also attend to the developmental trajectory of novice instructors. Our analysis of episodes suggests that instructors may first lean on structural scaffolds before developing the capacity to integrate discursive and practices that effectively broaden participation. PD, therefore, should be sequenced to support growth across these dimensions rather than treating scaffolding strategies as isolated techniques.

Conclusion

This study proposes a unified theory of group scaffolding in undergraduate mathematics, integrating four interdependent dimensions: norms setting, task and material design, discourse moves, and access distribution. By grounding our analysis in episodes of MGTA instruction, we illustrate how partial and emergent scaffolding practices highlight both the challenges instructors face and the critical elements required for effective group work. These episodes serve not only as empirical grounding but also as pedagogical resources for making visible the complex work that instructors must learn to do. Our contribution is twofold. First, we extend prior theories of scaffolding, discourse, and norms by showing how they can be synthesized into a coherent account of group scaffolding that better reflects the realities of undergraduate mathematics classrooms. Second, we argue that novice instructors provide a particularly generative site for theory-building and PD design, as their developing instructional practice could make visible gaps in instructional practice. For the field of undergraduate mathematics education, this unified theory provides a lens for analyzing group work and a guide for strengthening professional development opportunities that move instructors beyond fragmented approaches toward more integrated, collaborative scaffolding. Future work should further test and refine this framework in diverse classroom contexts, with attention to how it supports not only instructor development but also students' opportunities to learn collaboratively.

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