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Trust, Power, and Task: Conditions for Productive Collaboration in Mathematics Classrooms

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Abstract

Collaboration plays a crucial role in mathematics education, influencing student engagement, problem-solving and critical-thinking abilities, and classroom equity. Bridging the gap between theory and practice is an essential step to using and applying advancements in educational research. This study examines the implementation of collaboration and peer-to-peer discourse in classrooms across the United States, focusing on the specific strategies educators employ to enhance student participation in exchanging ideas through discussion. Through qualitative interviews with experienced math teachers and/or education researchers, the study aims to identify methods that foster collaboration and open, helpful peer-to-peer discourse. The study takes a systematic approach by examining classroom collaboration through three lenses: student trust and safety, power dynamics, and task selection. It finds that creating a comfortable environment where students can trust one another, a situation where teacher-student and student-student power dynamics are fair, and one where task structures are both challenging and accessible to the majority of the classroom are all key aspects to creating an environment conducive to productive collaboration.

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Introduction

Breakthroughs in pedagogical research on mathematics education have brought collaboration to the forefront of many new instructional techniques (Langer-Osuna, 2017). Students having the ability to articulate their ideas, compare their reasoning with that of their peers, and contribute to group discussions have begun to shape how educators design classroom instruction (Johnson & Johnson, 1999). Collaboration is now recognized as a key influence in deeper conceptual understanding and problem-solving skills.

With mathematics traditionally viewed as an individual endeavor, many instructional practices tend to focus on working through problems independently and demonstrating mastery through assessments that prioritize solitary work (Johnston, 1984). Unlike in subjects such as literature or history, where discussion is often an integral part of learning, mathematics has been generally framed as a series of clear-cut tasks with correct and incorrect answers (Sterenberg, 2004). It also tended to be an area where the teacher was the sole provider of instruction, and peer-to-peer power dynamics were seldom considered in instructional design. The traditional approach often led to a passive learning environment, where students received knowledge rather than actively constructing it through interactions with their classmates (Lee & Paul, 2023).

Students' abilities to collaborate are neither tested nor developed in a passive learning environment (Choi & Hur, 2023). However, a growing body of research suggests that mathematical thinking has a place as a social activity, benefiting from the exchange of ideas, multiple perspectives, and collective reasoning (Restivo, 2003; Vinckier, 2019; Rumack & Robichaux-Davis, 2019; Harper, 2019). Beyond this, collaboration in classrooms fosters essential interpersonal skills such as active listening, effective communication, and the ability to constructively critique others' ideas (McCrone, 2005).

Studies have found that students do not engage in collaborative behaviors at a high level unless they receive clear and explicit instruction on how to do so (Gillies, 2017), highlighting the need for strong instruction not only on mathematical concepts but also on the process of working effectively with others. Simply placing students in groups does not guarantee meaningful collaboration, as students may default to working individually, divide tasks inequitably, or struggle with communication barriers (Quinn et al., 2020; Donelan & Kear, 2024; Hussein, 2021). Any discourse that occurs can end up being surface-level or unhelpful to students.

Explicit instruction often involves modeling desired behaviors, setting clear expectations or norms, and providing structured opportunities for students to practice these skills. When teachers model collaborative processes, students are more likely to internalize and apply these behaviors in their interactions. Teachers who demonstrate effective communication, active listening, and respectful disagreement provide students with concrete examples to emulate, fostering strong interpersonal skills. Staples (2007) points out the teacher's role in organizing and participating in collaborative classroom practices, noting that effective facilitation requires a deep understanding of both mathematical content and group dynamics. Blatchford et al. (2003) found that primary and secondary teachers often do not prepare their students before giving them collaborative tasks, leading to less productive group interactions.

Pedagogical implementations of collaboration can take many forms. Recognizing its pivotal role, this study aims to explore specific strategies employed by educators to foster effective peer-to-peer collaboration. It aims to uncover practices that can be adopted to enhance student engagement, deepen conceptual understanding, and cultivate essential interpersonal skills that can be applied both in and outside the mathematics classroom.

Methodology

This study employs semi-structured interviews to investigate the implementation of collaboration in mathematics classrooms. The participants include experienced mathematics teachers and math education researchers from elementary, middle, and high schools across the United States. These individuals were selected to ensure a range of perspectives on collaborative teaching strategies.

Data collection consists of in-depth, one-on-one interviews conducted via video conferencing or in-person meetings. Each interview lasted approximately 30–45 minutes and followed a guide with open-ended questions designed to explore instructional techniques, group work structures, and methods for fostering productive peer discourse, as well as follow-ups for any points the participant made that required further clarification or elaboration. Out of the nine interviews conducted, the first three focus on general collaborative strategies, providing an overview of common techniques educators use to facilitate rich peer-to-peer discussions and group work. They were intended to provide foundational insights into general techniques, such as group formation, structured discussion, and assessing collaborative tasks, thereby creating a baseline understanding of standard practices and variations in how collaboration is approached across different educational settings.

The remaining six interviews are divided into three groups of two, with each pair of interviews exploring a specific aspect of collaboration in greater depth: student trust and safety, power dynamics, and task structure.

- The first subgroup, containing the fourth and fifth interviews, examines the cultivation of an environment where students feel safe expressing their ideas, taking risks, and engaging in mathematical discussions without fear of judgment. These interviews investigate methods such as norm setting and teacher interventions.
- The second subgroup, comprising the sixth and seventh interviews, focuses on the power dynamics between the teacher and students, as well as between students. They explore how factors such as perceived mathematical ability and teacher facilitation influence participation.
- The final subgroup, containing the eighth and ninth interviews, delves into task structure, analyzing how the design and framing of mathematical problems impact collaboration.

The interviews discuss the types of tasks that best promote robust, equal, and beneficial peer-to-peer discussion, for example, how open-ended versus procedural problems affect student interactions, and the role of scaffolding and productive struggle. With this structure, the study provides an analysis of both broad and nuanced factors influencing collaborative learning as well as techniques that educators employ to navigate these complexities. Thematic coding is applied separately to each subgroup, allowing for an in-depth examination of patterns within each focal area while also drawing connections between them.

Findings

Trust and Safety

Mistakes and Learning

The handling of mistakes in the mathematics classroom plays a fundamental role in student self-esteem and their willingness to take risks in discussions with their peers (Aksu et al., 2016; Wasilewski, 2023). Educators in this study noted the need for students to feel comfortable and safe in their classrooms if they wished to make any progress. In an environment where mistakes are normalized and treated as learning opportunities, students are more likely to trust both their teacher and their classmates (Donaldson, 2023). A key factor in influencing this willingness is psychological safety, in the sense that students feel comfortable expressing their ideas without fear of ridicule. When mistakes are framed as natural and expected, students feel less pressure to be perfect and more comfortable engaging in challenges such as contributing to group discussions. As one educator in the study noted, they always try to normalize it first by emphasizing the idea that others have also or will also make a similar mistake with the intent of making them feel less alone. The educator helps reduce the sense of isolation that often accompanies errors, allowing students to see their struggles as part of the broader learning process rather than personal shortcomings. They also put the students' learning in the context of a journey with their peers, creating teachable moments that benefit the entire classroom community and reinforce the idea of building understanding together. The same educator highlighted how a group with students who are willing to discuss their mistakes and admit to making a mistake often have the richest conversations, as these discussions allow students to critically examine misconceptions and refine their reasoning.

Another teacher noted the punitive, final nature of mistakes in a math class versus others, where students often get to rework drafts of essays to perfect them. The rigid perception of correctness and intelligence discourages students from taking risks, which is an essential component of collaborative problem-solving (Mangels et al., 2006; Hübner & Pfost, 2024). Multiple interviewees described using mistakes in some way to advance learning, whether it be analyzing and correcting or leveraging errors as discussion points to deepen student understanding. When students know their contributions, including incorrect ones, are valued, they become more comfortable engaging in discussions. Conversely, when students feel mistakes define their intelligence, they are less likely to contribute, leading to passive participation and reduced learning opportunities (de Kraker-Pauw et al., 2022). One educator noted that they believe their students "learn more from figuring out why an answer is wrong than just seeing the right answer, because odds are they will do it wrong eventually, and [the teacher wants] them to be able to identify that." This perspective reframes mistakes as valuable learning opportunities rather than failures, emphasizing the importance of understanding the reasoning behind answers rather than just memorizing procedures.

Prioritizing Thinking over Correct Answers

Traditional mathematics classrooms often emphasize arriving at the correct answer as the primary measure of success (Doganay & Bal, 2010; Guerra & Lim, 2017). However, many educators in this study argue that focusing solely on correctness can discourage deep engagement and reinforce the idea that math is about simply getting answers correct, regardless of the method, rather than understanding. Instead, they prioritize students’ thinking processes (i.e., how they approach problems, justify their reasoning, and revise their ideas) to create a more meaningful learning experience. One teacher explained the shift in focus by highlighting how they try to understand student thought processes rather than simply confirming whether they arrived at the right solution.

> It’s very rare that I ask a question that I don't already know the answer to. But what I don't know is how the learners are gonna think about it, how they're gonna move towards the answer, how they interpret the question.

By emphasizing reasoning and justification, this educator encourages students to explore multiple pathways to the solution instead of the one prescribed to them by the teacher. It is likely that they will have slightly different approaches to the question, hence allowing them to branch off into different solution paths from one another.
A major drawback of answer-driven instruction is that it often leads students to prioritize speed over reasoning (Cankoy & Tut, 2005; Ostler, 2011). The student who raises their hand first is generally the one who receives attention or praise, thus reinforcing the idea that mathematical ability is measured by how quickly one can produce a correct response. This dynamic discourages students who need more time to process problems, leading them to disengage or develop the misconception that they are “bad at math.” An interviewee described how this culture of quick and correct answers shapes student motivation to participate, saying that there will always be a handful of students who consistently seem to fit the bill of the “fast math thinkers” in traditional classrooms. However, this structure can implicitly discourage students who require additional time to process concepts and think through questions, leading them to withdraw from participation. As one teacher noted, many students have internalized the belief that if they cannot answer immediately, their contributions are not valuable. This perception can contribute to learned helplessness, where students begin to see themselves as incapable of success in mathematics simply because they do not conform to the narrow definition of mathematical ability that prioritizes speed over depth of thought (Yates, 2009; Odabasi, 2013).

To address this, some educators in this study slowed down their discussions and provided ample processing time for students to be able to engage. An effective strategy was to encourage students to turn and talk to their neighbors or a smaller group before raising their hands to discuss with the whole class. Teacher 3 noted an increase in participation when they used this method, explaining that students who might hesitate to speak in front of their peers felt more comfortable practicing articulating their ideas in a smaller setting first.

Power Dynamics

Student Perceptions of Themselves and Others

Students tend to enter mathematics classrooms with pre-existing ideas of who is “good at math” and who is not (Bui et al., 2023), a phenomenon pointed out by multiple educators in this study. These perceptions are shaped by various factors, including previous academic performance, teacher reinforcement, social status, and stereotypes associated with race and gender (Wolff, 2021; Dersch et al., 2022). Over time, these labels can become ingrained in students' behaviors and self-perceptions, influencing their interactions with peers in collaborative learning environments (Kitchen et al., 2017).

A key strategy discussed by interviewees is intentionally disrupting the fixed perceptions of mathematical ability. Many students internalize the idea that being good at math means being fast and accurate (Boaler et al, 2015), leading them to either over-reliance on certain peers during group work or hesitation to contribute due to fear of making mistakes (Wasilewski, 2023). Teacher 7 suggested tasks that require multiple forms of mathematical thinking (e.g., problem-solving tasks), noting that they "level the playing field." Non-routine tasks can give students new tasks that challenge different skill sets and ways of thinking.

Another effective approach brought up by Teacher 6 is using assigned competence to redefine success in the classroom. Assigned competence is a strategy in which teachers publicly recognize and validate different types of contributions that students make to group work, dismantling the narrative that there is only one type of valid contribution (Johnson et al., 2022; Johnson, 2017). Rather than only praising correct answers, educators highlight valuable mathematical thinking, such as insightful questions, creative problem-solving approaches, or effective communication. An educator described that this approach helps to highlight that "there's more than one way to be 'good at math,'" encouraging students to expand their view of what it means to contribute in a math classroom.

Structured turn-taking stabilizes the dynamics of who gets to participate in group discussions. One teacher implemented a system where "nobody speaks twice until everyone speaks once" to ensure that dominant voices do not overshadow quieter students. This rule encourages hesitant students to engage while also helping more confident students recognize the importance of listening to others. Overall, students are more mindful of their classmates. Structured participation methods help shift classroom culture away from a competitive environment where a handful of students contribute and the majority disengage (Kim & Harper, 2019).

Teachers in this study also intervened strategically to shift student perceptions in real-time. When a group defaults to letting one student take over, the teacher may step in and redirect the discussion, prompting quieter students to contribute. One educator described how they monitor group interactions and occasionally step in with targeted questions to encourage broader participation and signal to students that diverse input is expected and valued.

Small Group Composition

The composition of smaller groups in a mathematics classroom plays a crucial role in determining the effectiveness of collaborative learning. How students are grouped, whether by ability, familiarity, or other factors, can impact participation, peer interactions, and the overall success of group work (Oh, 2019; Marr, 2024). The educators in this study had differing opinions on how students should be grouped, with the two main approaches being randomized grouping and teacher-selected grouping.

Some educators in the study advocated for randomized grouping as a way to promote equity and expose students to a variety of perspectives. By assigning groups randomly, teachers prevent the reinforcement of social hierarchies and status differences that can emerge when students consistently work with the same peers (Liljedahl, 2014; Samudra et al., 2024). One teacher explained that randomization helps students recognize that "everyone has something valuable to contribute, regardless of whom they're working with." Having students work with different classmates throughout the year also broadens their exposure to diverse problem-solving approaches, fostering adaptability and collaboration skills. Additionally, randomized grouping can help prevent the innate labeling that can occur with teacher-assigned groups, such as the assumption that the teacher meant certain students to be the "leaders" of the group.

Also, randomizing groups frequently seemed to improve the synergy of whole group discussions, as students had already worked with everyone else in the room and thus were more comfortable sharing their ideas in a larger class setting. Students who had previously collaborated in small groups were more likely to engage in whole-class discussions, as they had already built familiarity with their peers, so they were not presenting to unfamiliar faces. This approach also helps prevent students from becoming overly reliant on the same individuals for guidance, encouraging them to develop their own problem-solving skills. Some educators noted that the randomized grouping method works with intentional guidance and light scaffolding, such as brief team-building activities or reflection prompts, to help students adjust to new group dynamics each time they are reassigned.

Other educators preferred teacher-selected groups and believed that strategic grouping allows for a more intentional balance of skills, personalities, and working styles. Teachers who took this approach often aimed to create groups where personalities complemented one another, such as grouping stronger students who are willing to help with students who may need more support but are eager to learn. More than just ability is considered, as one teacher explained that they factor in character traits, willingness to discuss mistakes with their teammates, and ability to keep up productive discussions. Teacher-selected groups allow educators to create an intentional balance where students complement each other's strengths. The primary educator who used intentional grouping in this study generally attempted to maintain balance with their table groups. If a group is composed entirely of dominant voices, discussions may become competitive rather than cooperative. Conversely, a group of reserved students may struggle to engage deeply with the material. Thus, teachers may deliberately balance groups by including students with different communication styles.

Placing students together can also help students build bonds with unfamiliar classmates, fostering a more collaborative environment. When students work with peers they do not usually interact with, they are exposed to different problem-solving approaches, communication styles, and perspectives (Sit, 2012). This not only broadens their mathematical thinking but also encourages them to develop interpersonal skills such as active listening and constructive feedback. Unfamiliarity is purposeful with the teacher-selected groups, where complementary skills of two students who may not have interacted otherwise have a chance to interact in a structured setting.

Task Selection

Open-ended and Open-middle Questions

Open-ended questions are characterized by their broad scope that allows students to explore multiple solution paths and justify their reasoning (Viseu & Oliveira, 2012; Chan, 2005). Teacher 9 describes using real-world examples, such as price comparisons at restaurants or decisions about purchasing shoes, to engage students in mathematical discussions. These tasks "give lots of opportunities for students to share opinions, and they love sharing their opinions" because there is "not necessarily one right answer." The absence of a single correct answer helps encourage students to focus on their reasoning and problem-solving process, rather than merely arriving at an expected solution with less exploration. When there are multiple approaches to the same problem within a group of students, it creates a natural space for discussion and deeper conceptual understanding (Gordy et al., 2020; Kozhevnikov et al., 2014).

Mathematical modeling was noted as a type of open-ended question that requires students to combine math knowledge and real-world solutions. These tasks are meant to develop an appreciation for the application of mathematics beyond the classroom and provide students with a goal to work toward, instead of plain, repetitive questions to drill. When analyzing and modeling real-world scenarios, groups have to make decisions using critical thinking skills, such as which variables to use in their models and which to discard. Students must evaluate different assumptions and refine approaches to create viable solutions, which is an act that requires discussion of a higher order. Teacher 8 emphasized that "students have to be able to justify why they are making the choices that they are making" when engaging in these problems, which further strengthens their analytical thinking and communication skills.

Open-middle tasks offer a structured problem with multiple solution paths, making them distinct from open-ended tasks while still promoting deep mathematical thinking. These problems have a defined beginning and end, but leave the middle open for exploration. For example, an open-middle problem might require students to determine missing values in an equation while following specific constraints. Teacher 8 describes an example involving factoring quadratics, where students work with an equation like x^2 + ?x +? = (x + ?)(x + ?) using only numbers from a defined set. This specific open-middle task reinforces conceptual understanding of quadratic multiplication. Instead of simply applying a memorized factoring and multiplying algorithm (such as FOIL), students must actively engage with the structure of quadratic expressions, exploring the relationships between coefficients and their factored forms. Students must consider how different number placements affect the expansion of the binomials. Rather than working through a predetermined sequence of steps, they experiment, adjust, and refine their reasoning to meet the given conditions. One potential approach a student might take is to start by analyzing the sum and product of the numbers they need to fill in. If the problem requires using only the digits 1 through 6, for example, students may begin by listing out all possible factor pairs that multiply to the final constant term and determining which pairs also add up to the middle coefficient. Another student might work backward—expanding a factored form using numbers from the given set and using trial and error to come up with the correct set of numbers. Students may arrive at different partial solutions and compare their reasoning, as helpful collaboration is difficult when every student is at exactly the same place (Hallam & Ireson, 2005; Murphy et al., 2017).

Open-middle and open-ended tasks serve different purposes in mathematics education, each playing a distinct role in fostering conceptual understanding. Open-ended questions allow students to explore multiple solution paths and do not particularly have a goal, making them useful for initial exploration. In contrast, open-middle tasks present a well-defined problem with a single correct answer, but allow students different paths to reach a solution. Another key distinction is that open-middle tasks create structured opportunities for productive struggle. Because there is only one correct answer, students must persist through trial and error, adjusting their approach based on feedback from their own reasoning or discussions with peers. Open-ended tasks, while also promoting discussion and justification, do not necessarily require students to converge on a single answer, allowing for more diverse perspectives and interpretations.

Starting with Accessible Tasks

A strategy used to make sure all students are engaged is designing tasks that provide all students with an entry point. When students encounter a problem, their willingness to engage is often tied to whether they feel capable of beginning the task (Hammad et al., 2022; Mulyani, 2020; Stevens et al., 2004), as noted by Teacher 4. With problems that seem too complex or do not have a clear starting point for students, teachers noted disengaging behavior prior to even attempting a solution. To combat this, teachers in this study, such as Teacher 8, designed tasks so that students had an entry point, whether it be collecting observations or identifying patterns, making comparisons, or drawing from prior experiences. By ensuring that all students can contribute in some capacity, teachers help reduce anxiety and hesitation, fostering a classroom culture where participation feels accessible to everyone. These entry points are particularly important for students who may lack confidence in their mathematical abilities, as they provide a way to engage without immediately requiring high-level computations or procedural recall. A key to this type of task is that there is no correct answer, and the floor to access the task is low. Activating prior knowledge in their students, a strategy used by Teacher 9, is done through activities attached to the main task or related warm-up exercises.

Three-Act Tasks, structured to gradually introduce mathematical concepts by sparking curiosity and discussion, were mentioned mainly by Teacher 8. The first act serves as a low-stakes entry point by presenting a real-world scenario or engaging visual that invites students to make observations. Teacher 8 explained that the initial step of making observations is one that generates discussion due to its accessibility to all students and the absence of barriers to mathematical ability. Thus, an increased number of perspectives leads to a diversified range of ideas, allowing students to engage with the task in different ways. Some students may notice numerical relationships, while others may focus on contextual details or visual patterns. Returning to the point of richer discussions when students have different levels of knowledge—similar to filling the gaps—the differing observations lead to students having something unique to share.

Conclusion

Collaboration in the mathematics classroom is a critical yet complex component of effective instruction. This study set out to analyze the methods that practicing teachers use to foster collaboration and aimed to bridge the gap between educational research and classroom practice. Interviews with experienced teachers help to provide real-world examples of collaborative strategies that promote student engagement, equitable participation, and deeper mathematical thinking. Key takeaways from this study include intentional methods of structuring discussions, group compositions, problem types, and other aspects of instructional design.

The study highlighted several aspects that influence collaboration in mathematics classrooms. First, the way mistakes are framed impacts students' willingness to engage. When mistakes are treated as valuable learning opportunities rather than failures, students feel more comfortable taking intellectual risks and contributing to discussions. Second, the prioritization of thinking over correct answers shifts the focus from speed and accuracy to deeper conceptual understanding, taking pressure off of students to have correct answers and encouraging students to explore rather than play it safe with familiar methods. Third, student perceptions of themselves and their peers influence group dynamics. Teachers and past experiences with peers play a crucial role in disrupting or building fixed mindsets about mathematical ability. Fourth, small-group composition affects collaboration in different ways, with different approaches, such as randomized or teacher-selected grouping, offering different benefits. Fifth, the use of open-ended and open-middle questions fosters rich mathematical discourse and allows students to engage with problems in ways that encourage discussion, justification, and multiple solution paths. Finally, beginning with an accessible task ensures that all students can participate from the outset, sparking discussion and increasing motivation.

Limitations

The sample size consisted of nine educators, which, while providing in-depth interviews with questions tailored to each interviewee, may not capture the full spectrum of collaborative strategies used in diverse classroom settings. Future research could expand upon this by incorporating larger and more diverse samples, as well as longitudinal studies that examine how collaborative strategies evolve over time and impact student learning outcomes. Other studies have cemented the importance of fostering collaboration in mathematics classrooms. As this study has shown, well-implemented collaborative practices enhance student engagement and improve problem-solving skills. Mathematics is often perceived as an individual subject, but when students are given opportunities to discuss, challenge, and refine their ideas collectively, they develop a deeper and more nuanced understanding of mathematical concepts. By learning from practicing teachers and adapting research-based approaches to real-world classrooms, this study highlights the tangible strategies educators can use.

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