

RESEARCH ARTICLE

Elementary preservice teachers' use of prompts to encourage student-to-student talk during simulated argumentation discussions

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Abstract

Providing opportunities for students to talk directly with their peers is a critical dimension to facilitating discussions in mathematics and science, including argumentation-focused discussions in which students construct arguments and critique others' arguments. Research suggests that supporting student-to-student talk and facilitating argumentation discussions are complex and challenging practices for preservice teachers (PSTs). Elementary PSTs from two mathematics and two science methods courses practiced facilitating student-to-student talk within the context of an argumentation-focused discussion. This study's main purpose was to explore the prompts that 29 PSTs used to encourage student-to-student talk in a simulated classroom. Findings show the PSTs were able to use direct prompts that encourage student-to-student talk but were just as likely to use prompts that may discourage students from talking to each other. Most direct prompts PSTs used to encourage student-to-student talk were for the purpose of argumentation construction and/or critique. PSTs were more likely to use indirect prompts, much like Talk Moves, that encourage students to consider others' ideas rather than requesting that students talk with each other. These findings have important implications for future research, as well as for teacher educators and professional learning facilitators who support teachers learning to encourage student-to-student talk during argumentation-focused discussions.

KEYWORDS

classroom discourse, teachers and teaching, teacher education

1 | INTRODUCTION

Facilitating discussions in mathematics and science classrooms in which students are encouraged to talk to one another aligns with recent reforms' emphasis on student-centered learning (National Governors Association Center for Best Practices & Council of Chief State School Officers [NGA & CCSSO], 2010; Next Generation Science

Standards [NGSS] Lead States, 2013). When students are given opportunities to engage in student-to-student talk, they are able to: (a) develop a deeper conceptual understanding of the content (Smith & Stein, 2018) through the co-construction of knowledge (Palincsar, 1998; Vygotsky, 1978); (b) engage in the discursive practices of mathematicians and scientists (Jiménez-Aleixandre & Erduran, 2008; Witherspoon et al., 2022); and (c) develop

everyday communication skills (Jiménez-Aleixandre & Erduran, 2008; Witherspoon et al., 2022). However, facilitating discourse between students is challenging for pre-service teachers (PSTs) (Bofferding & Kemmerle, 2015; Davis & Palincsar, 2022; Haverly et al., 2020; Murphy, 2016) for a number of reasons: (a) this approach is different from their own learning experiences (Melhuish et al., 2020; Michaels & O'Connor, 2012); (b) they fear losing control of the classroom (Davis et al., 2006; Haverly et al., 2020; Stein et al., 2008); (c) navigating unanticipated ideas in the moment cannot be fully planned (Ghousseini, 2015; Shaughnessy et al., 2021); and (d) peer talk is often not an established norm in their field experience classrooms (Boerst et al., 2011). Although not the focus of this study, encouraging student-to-student talk is also difficult for inservice teachers (Edmondson & Choudhry, 2018). Given the complexity of facilitating discussions in the regular classroom setting, Boerst et al. (2011) and Shaughnessy et al. (2021) recommend that teacher educators (TEs) decompose this practice into smaller routines that PSTs can learn and practice.

Our study focuses on how PSTs encourage student-to-student talk as they facilitate a mathematics or science argumentation discussion in a simulated classroom for the first time. As we will discuss in the following section, engaging students in talking to one another is a key facet of argumentation. Thus far, the literature has emphasized the challenges that PSTs have supporting student-to-student talk in complex classroom settings. Given PSTs' limited experience facilitating student discourse, we were curious about the specific prompts PSTs would use to encourage student-to-student talk during an argumentation-focused discussion in a less complex simulated teaching environment. TEs who support PSTs with learning how to encourage student-to-student talk could benefit from this study's results by having PSTs reflect on the prompts they use and expose PSTs to a wider range of prompts to encourage students to talk to each other. In what follows, we first summarize key ideas about student-to-student talk. We then discuss argumentation as a key practice in mathematics and science instruction for co-constructing knowledge, which is supported through student-to-student talk. Finally, we share our theoretical framework which draws from social constructivism and a model of disciplinary argumentation.

2 | LITERATURE

2.1 | Student-to-student talk in mathematics and science classrooms

Encouraging students to talk to each other requires teachers to act as facilitators (Confrey & Kazak, 2006; Lloyd & Murphy, 2023). This approach to facilitating a

productive academic discussion differs from discussion strategies that are teacher-centered, such as the Initiate-Respond-Evaluate (IRE) strategy (Cazden, 2002; Lemke, 1990) and the "show and tell" approach (Kazemi & Stipek, 2001; Stein et al., 2008). When implementing the IRE strategy, teachers initiate (I) a student response, a student responds (R) to the question, and the teacher immediately evaluates (E) the response given. By using the IRE strategy, teachers can check what students remember (Michaels & O'Connor, 2012); however, this approach inhibits students from talking to each other, limiting their opportunity to learn (Cartier et al., 2013; Rees & Roth, 2019). Similarly, the "show and tell" approach consists of the teacher eliciting multiple students' ideas without helping the students make connections between their ideas or challenging the thinking of others to reach a consensus (Bofferding & Kemmerle, 2015; Stein et al., 2008).

Lloyd et al. (2016) suggest using the Facilitate-Listen-Engage (FLE) method to facilitate productive discussions. In this student-centered model, the teacher and students converse "as equal contributors in a cohesive dialogue" (Lloyd et al., 2016, p. 295) and "students share in conversation-like dialogue" (Lloyd et al., 2016, p. 296). The facilitate (F) part requires teachers to "act as a tour guide leading students through an interactive process of learning" (p. 296). The listen (L) part emphasizes active listening by the teacher and students. The engage (E) part occurs when teachers facilitate shared communication, including student-to-student talk.

In addition to using discourse-supportive approaches like FLE, teachers must establish student-to-student talk as a classroom norm (Shaughnessy et al., 2021; Windschitl et al., 2020) and frame the discussion (Mikeska et al., 2019; Shaughnessy et al., 2021) with this focus. Teachers also need to ask high-level thinking questions that generate discussion between students and invite a range of responses (Lloyd & Murphy, 2023; Smith & Stein, 2018; Windschitl et al., 2020). Direct prompts are specific questions or statements that teachers use to get students to talk to each other (Lottero-Perdue et al., 2022; Windschitl et al., 2020), such as "Jayla, can you explain to Will the reason you think the amount of matter did not change?" The goal of this question is for the students to engage in a back-and-forth dialogue rather than talking to or through the teacher.

Using "talk moves" (Chapin et al., 2013; Michaels & O'Connor, 2012) is another instructional strategy PSTs can learn to encourage students to engage in student-centered discourse. Partner talk, also called "turn-and-talk," is one talk move that encourages students to talk to each other (Chapin et al., 2013; Michaels & O'Connor, 2012). Most talk moves indirectly prompt students to communicate with each other by asking students

to think about each other's ideas (e.g., "Do you agree or disagree with what Jayla shared?").

Within mathematics and science education, PSTs struggle to foster student-to-student talk (Bofferding & Kemmerle, 2015; Davis & Palincsar, 2022; Haverly et al., 2020; Murphy, 2016) unless training is provided (Cartwright, 2012). Cartwright (2012) explored how PSTs facilitate science talks in an after-school program and found that training supported PSTs in being able to empower students to speak and address their peers.

Haverly et al. (2020) and Davis and Palincsar (2022) found that PSTs could elicit student thinking during a whole-class science discussion; however, it was difficult for them to encourage students to consider one another's ideas and respond directly to each other. Similarly, Murphy (2016) and Bofferding and Kemmerle (2015) explored how elementary novice teachers facilitate mathematics talk in the classroom, finding that (a) PSTs struggled to balance collaborative talk and mathematics content, and (b) most talk was between the teacher and students.

Based on these studies, the regular classroom appears to be a complex environment for PSTs that are just beginning to develop the pedagogical skills needed to facilitate student-to-student talk. Approximations of practice (Grossman et al., 2009) are one-way PSTs can practice implementing new strategies they are learning in a less complex environment. Common approximations include role-playing, microteaching, and teaching rehearsals (Benedict-Chambers, 2016; Lampert et al., 2013). More recently, digital simulations are being used to help PSTs develop their instructional skills (Mikeska & Howell, 2020; Lottero-Perdue et al., 2022; Codreanu et al., 2022; Johnson & Kim, 2021); however, PSTs encouragement of student-to-student talk has not been explicitly explored in this environment. Therefore, in this study, we explore how PSTs facilitate student-to-student talk within the context of a mathematics or science argumentation discussion that occurred in a Mursion® simulated classroom. Furthermore, we examine the specific prompts the PSTs used to encourage student-to-student talk, as previous studies did not examine the strategies PSTs were using in detail. Thus, this study fills these research gaps.

2.2 | Disciplinary argumentation in mathematics and science classrooms

Disciplinary argumentation is a key mathematics and science practice discussed in reform documents (NGA & CCSSO, 2010; NGSS Lead States, 2013). For example, "engaging in argument from evidence" is one of the eight science and engineering practices in the NGSS (NGSS

Lead States, 2013). Similarly, "construct viable arguments and critique the reasoning of others" is one of the eight standards for mathematical practice outlined in the *Common Core State Standards for Mathematics* (NGA & CCSSO, 2010).

Acknowledging that there are disciplinary distinctions between mathematical and scientific argumentation, scholars within each discipline do define argumentation in similar ways. In mathematics education, Staples and Connor (2022) define argumentation "as the process of making mathematical claims and providing evidence to support them" (p. 4). Within science education, argumentation is defined as "a response, or claim, to a question about the natural world that uses evidence and reasoning to justify the claim" (Mikeska & Howell, 2020, p. 1364). Notwithstanding these quotes, the term "justification" is more often used in mathematics while the terms "evidence and reasoning" are used predominantly in science (Witherspoon et al., 2022). Given the parallels between evidence/reasoning (in science) and justification (in mathematics), we combined these components of argumentation in our analysis and findings.

2.3 | Theoretical framework

Mikeska et al. (2019) identified five dimensions teachers need to implement to effectively facilitate a student-centered, argumentation-focused discussion. Those dimensions include: (1) attending to students' ideas responsively and equitably, (2) facilitating a coherent and connected discussion, (3) encouraging student-to-student interactions, (4) developing students' conceptual understanding, and (5) engaging students in argumentation (p. 138). Our study design and analysis were informed by the third and fifth dimensions, respectively. Encouraging student-to-student talk is essential to student learning in both mathematics and science, as this form of discourse affords students the opportunity try out new ideas as well as consider and critique the ideas of their peers (Smith & Stein, 2018). These collaborative efforts help students grasp ideas they likely would not understand on their own (Ellis, 2011; Smith & Stein, 2018). This view of how people learn is consistent with the theoretical construct of social constructivism (Palincsar, 1998; Vygotsky, 1978).

Since student-to-student talk is an essential aspect of productive argumentation discussions (Mikeska et al., 2019), engaging students in disciplinary argumentation aligns with a social constructivist approach to learning (Cobb & Yackel, 1998; Driver et al., 2000). Disciplinary argumentation is rooted in Toulmin's (1969) discipline agnostic framework which includes: (a) a claim

which is a statement that addresses the question or problem, (b) evidence which is data that supports the claim, and (c) reasoning which connects the evidence to the claim. This epistemic structure is called argument construction (Jiménez-Aleixandre & Erduran, 2008; McNeill et al., 2016). Another component of argumentation is argument critique, the dialogic process where students engage in a rebuttal (Toulmin, 1969) and critique one another's arguments (Jiménez-Aleixandre & Erduran, 2008; McNeill et al., 2016).

3 | STUDY PURPOSE

In this study, we examine to what extent the PSTs implemented a social constructivist approach by analyzing whether and how they encouraged student-to-student talk within mathematics or science argumentation-focused discussions. Specifically, we examined the prompts PSTs used that (a) were posed to encourage students to share their constructed arguments or critique the arguments of their peers, and (b) either supported or discouraged student-to-student talk. Our goal was to gain an in-depth understanding of these prompts within a lower complexity simulated classroom environment, which we hypothesized might have three specific affordances. First, it might make it more likely for PSTs to support student-to-student talk. Second, it makes their prompts more visible to us as researchers given the simultaneous generation of a video discussion, which is easily converted to a transcript. Third, it allows us to compare across PSTs who are all teaching the same simulated students and, for each disciplinary area, facilitating a discussion in response to the same task. As such, we asked the following research questions (RQs): What prompts do PSTs use to encourage student-to-student talk and what purpose do they serve with respect to disciplinary argumentation? (RQ1) What prompts do PSTs use that may discourage student-to-student talk? (RQ2) How does PSTs' encouragement of student-to-student talk differ across PSTs? (RQ3).

Note that we did not pose a research question comparing prompts used in mathematics versus science discussions. Despite aforementioned differences in argumentation across these disciplines, our previous research has suggested that there is greater variability across individuals than across content areas (Mikeska et al., 2022). Also, our focus was on student-to-student talk, which is more generalizable across disciplines. As explained in the next section, each PST participant facilitated a mathematics or a science discussion, not both (which would enable a stronger ability to compare); and

the mathematics and science simulation tasks we used in the study emphasized similarities in argumentation strategies despite content differences.

4 | METHODS

4.1 | Participants

Twenty-nine PSTs enrolled in two elementary science methods courses ($n = 16$) and two elementary mathematics methods courses ($n = 13$) in spring 2021 participated in the study. Of these, 26 identified as female, two as male, and one preferred not to respond. Regarding race and ethnicity, 22 identified as white, two as black, two as Asian, one as other (Caribbean), and three as Latinx; one PST identified as white and Latinx. Of the 29 PSTs, 59% reported never having facilitated a discussion in simulated environment prior to the study, 24% had done so once or twice, and 17% had done so three or more times. These PSTs were part of a larger study, the Online Practice Suite (OPS) Project, which aimed to investigate how PSTs learn to facilitate argumentation discussions using simulations. The four methods courses were taught by two science (TE1 and TE2) and two mathematics TEs (TE3 and TE4).

4.2 | Study context

4.2.1 | Simulated classroom and discussion

As part of the OPS Project, all 29 PSTs facilitated a private 20-min mathematics or science discussion in the upper elementary Mursion[®] simulated classroom. The classroom includes five student avatars—Mina, Will, Jayla, Emily, and Carlos (Figure A1, Appendix)—who are all played by a human simulation specialist (hereafter, “sim”) in real time. Mursion[®] has been identified as both a “mixed reality” and a “virtual reality” environment in the literature. Those who identify it as mixed reality, do so in reference to the blending of digital (e.g., avatars) and real world (e.g., the human sim) elements (Bondie et al., 2021). Others have argued that Mursion[®] is an example of virtual reality because of its “perceptual capacity to approximate specific embodied experiences of teaching actual students” (Kosko et al., 2021, p. 267). Kosko et al. (2021) juxtaposed this type of environment with augmented or mixed reality that “informs how the PST interacts with the environment at hand” (p. 266). We agree that Mursion[®] is not classified as mixed reality given this perceptual capacity

framing but also see the utility in describing the Mursion® environment as a mix of real and virtual elements.

Sims in the OPS Project received extensive training from Mursion® and the OPS Project team to voice and control the student avatars, learn how to respond as each student avatar as specified in the discussion scenario, and know when to change their thinking during the argumentation discussion (e.g., enough evidence-based reasoning is presented). This training, along with feedback from Mursion® and OPS Project trainers, is the primary way in which sims learn to respond consistently across PSTs, despite variation in PSTs' approaches to discussions and the specific prompts they use (Bondie et al., 2021). At the beginning of every discussion, the sim demonstrates that the student avatars can talk directly to each other. For the remainder of the session, the sim is trained to only engage in student-to-student talk when encouraged to do so. If a PST prompts student-to-student talk, but then interjects after one student responds, the sim will not acknowledge the initial prompt. Asking students to raise their hands and be called on is another signal that would result in the sim to not have student avatars talk to each other.

About one week prior to facilitating their first discussion in the simulated classroom, the PSTs received preparatory documents, including (a) a description of the Mursion® upper elementary simulated classroom and (b) the discussion task. For science, the discussion task was called "Making Lemonade" and was about conservation of matter (Mikeska et al., 2021). For mathematics, the task was called "Emily's One Less Method" and was about fractions (Howell et al., 2021). Although content details vary across the tasks, both were designed based on the same five dimensions of argumentation-focused discussion (Mikeska et al., 2019), one being student-to-student talk. Both tasks describe students' prior learning, include copies of student work, provide the discussion goal, and list and describe the dimensions.

4.2.2 | PST preparation by TEs in methods courses

All TEs engaged their PSTs in referencing the literature on dimensions of argumentation-focused discussion (Mikeska et al., 2019) or talk moves (Chapin et al., 2013; Michaels & O'Connor, 2012); analyzing videos or transcripts of discussions; and creating discussion frames, which are graphic organizers to help prepare the PSTs to facilitate a discussion. In addition, all TEs had PSTs identify prompts within transcripts of others' discussions that

encouraged students to consider other's ideas and write such prompts within their discussion frames.

There were some differences in preparation across the TEs. TE3 did not reference the dimensions of argumentation discussions (Mikeska et al., 2019), and TE1 did not introduce talk moves (Chapin et al., 2013; Michaels & O'Connor, 2012). Only TE1 and TE4 asked PSTs to identify prompts in transcripts that directly encouraged student-to-student talk. Finally, only TE1 asked PSTs to include such prompts within their discussion frames.

4.3 | Data sources

The primary qualitative data source was 29 de-identified transcripts from the PSTs discussions. Videos served as a secondary source to clarify unclear transcript excerpts.

4.4 | Data analysis

Our analysis was an iterative and collaborative process of generating and revising codes and applying them to PST prompts within the transcripts. We used qualitative content analysis (Schreier, 2012) by creating a coding frame to describe PSTs' prompting of student-to-student talk. Qualitative content analysis originates from and expands on quantitative content analysis, drawing heavily upon a priori codes in a coding frame; however, its qualitative nature allows for data driven (emergent) codes to be included to fully describe the data (Schreier, 2014).

Addressing RQ1, we began by applying two a priori codes to describe prompts that PSTs used to directly encourage student to student talk: turn-and-talk prompts and talk-to requests (see Table 1). Turn-and-talk prompts ask students to turn to one another and discuss (Chapin et al., 2013; Michaels & O'Connor, 2012). In the Mursion® simulated classroom, this results in a mumble that involves students talking to one another but does not reveal clear information about the substance of the talk. Talk-to prompts directly ask students to talk to one another (e.g., "Jayla, can you tell Will ...?") (Mikeska et al., 2019; Windschitl et al., 2020). If successful, this prompt results in back-and-forth talk that is discernable to the PST. We located within the transcripts where talk-to prompts occurred during the discussion and where three or more consecutive turns of student talk (e.g., Mina then Jayla then Emily) followed the prompt without teacher interruption. We applied another a priori code, framing, to statements PSTs used to prepare students for and encourage student-to-student talk, typically at the beginning of the discussion (Mikeska et al., 2019).

TABLE 1 Codes and examples.

Category/code	Examples
Direct encouragement	
Turn-and-talk	"I would like us to turn and talk to our partner and discuss which property, weight, or volume will help us to determine if the amount of matter changed or not in our investigation. Okay?" (Grace, Science) "Is [Emily's one-less method] going in the toolbox? Is it not? So you can turn and talk amongst yourselves and your peers and your partners and the other group to all come together and figure out what we're going to do." (Nicholas, Math)
Talk-to request	"Jayla, do you agree or disagree with Will and Emily's observations? Go ahead and tell them." (Erin, Science) "So Emily, can you ... try to convince Will and Mina that this is a great method to use? Cause they don't seem to believe you." (Vaani, Math)
Indirect encouragement	
Framing	"We're going to start by having each group share what they found in their investigations ... and feel free to ask questions and agree or disagree with each other." (Ava, Science) "So right now we're just going to be sharing our answers together and having a discussion about them." (Savannah, Math)
Tell the class	"[Mina] ... do you want to tell us a little bit about what you found in your investigation? ... Did the amount of matter change when you combine the ingredients? And then any explanation you have." (Isaac, Science) "So does anyone want to talk about the importance of the fraction number line? Just explain to your peers whether it is helpful ..." (Willow, Math)
Consider others' ideas	"So Jayla just said that weight is the amount and volume is just how much space it takes up ... Emily and Will, what do have to say about that?" (Leah, Science) "Okay. How about Jayla? Do you agree with Mina that Emily's method works to find fractions in between two-thirds and seven-eighths?" (Qabila, Math)
Discouragement	
Tell me	"Okay ... Carlos and Mina, can you tell me what your thoughts are about the amount of matter after are making lemonade investigation? And can you tell me what evidence you have to support your claim ...?" (Caroline, Science) "Okay. And tell me, did you guys think that this was a method worth keeping in your toolbox?" (Oliver, Math)
Raise hands	"If you could, I would like you to raise your hand because we're still going to respect when others are speaking and we want to raise our hand so we don't interrupt others ... Any other questions before we begin?" (Haley, Math) "Okay, now ... Now, I'm going to ask all of you, raise your hand ..." (Tara, Math)

As such, framing indirectly encouraged student-to-student talk as it did not occur immediately following the prompt.

Working in coding pairs, the authors co-coded two science and two mathematics transcripts for turn-and-talk, talk-to prompts, and framing statements. We also described the purpose of each turn-and-talk and talk-to request, using the prompts themselves and the surrounding discussion. The remaining 25 transcripts were divided among the first four authors, each coded independently by two. We calculated intercoder agreement for each code by dividing the number of coding assignments the two coders agreed upon out of the final set of codes used in the study. Intercoder agreement was as follows: turn-and-talk, 97% (34 instances); talk-to prompts, 81% (34 instances); and framing, 100% (7 instances). Coding pairs met to discuss and reconcile differences in coding. We also randomly selected five science and five

mathematics transcripts for an author who had not originally coded those transcripts to review.

Four other codes emerged during coding process, adding to our coding frame: tell the class, consider others' ideas, tell me, and raise hands (Table 1). The first two were forms of indirect encouragement. The code, tell the class, involved the PST asking a student to communicate to the class in a broad way. The code, consider others' ideas, identified when the PST asked the students what they thought about ideas that others shared during the discussion. The two other emergent codes may have discouraged students from talking to one another. The code, tell me, was used when the PST explicitly asked the students to tell the teacher. We also used the code, raise hands, when the PST asked students to raise their hand before speaking or to not blurt out. These four emergent codes were used while reconciling a priori codes.

TABLE 2 Purpose subcodes and examples.

Subcode	Examples
Claim	“Can we all agree that it was easy to use but it's for very specific questions? ... So now consider the statement I just made and talk amongst your partner and also the other group about what we can all agree on in this situation.” (Nicholas, Math) “Alright, let's come to a final consensus about whether or not matter was conserved. Let's have one more turn and talk with your neighbors and discuss whether or not matter was conserved in our investigation.” (Erin, Science)
Evidence/reasoning or justification	“Both of your groups had different ideas on the last question. Would you keep it in your toolbox? Mina and Will's group decided that no, you cannot keep it in your toolbox because it doesn't work enough of the time. Carlos, Emily, Jayla's group stated that yes, we can keep it in the toolbox because it's quick and easy. I want for the two groups to discuss why or why not we can keep it in the toolbox.” (Victoria, Math) “So Jayla, could you tell Carlos and Mina why you decided to take two different weights [before and after mixing]?” (Anna, Science)
Critique	“So Emily, I'm going to call on you because I know that you said that you would want to use it because it's quick and easy. What would you say to Mina and Will about it not working all the time and therefore we should not use it?” (Nicholas, Math) “And how about we take a minute or two and we'll go ahead and turn and talk and let's see if the rest of your classmates agree with what you have said, Jayla, and then we can talk about it as a class on whether we believe that matter was conserved or not.” (Bailey, Science)
Other	[After Emily said “But we also figured out that this method works best when the denominators are far apart. And that's how we came up with three-fourths and 89-ninetieths”] “You can work with your partners and do this now. [turn-and-talk request] Class. We can come back. Does anyone want to volunteer any fractions that they found between three-fourths and 89-ninetieths?” (Willow, Math) “Okay. I hear us talking a lot about volume and matter and weight. So I'd like to see if we can come to an agreement about whether or not matter had changed in our experiment. Um, so before we begin, I'm going to give you a moment to turn and talk with each other about what volume matter and weight mean. You can go ahead now.” (Jocelyn, Weight)

We also categorized the purpose of the PSTs' use of turn-and-talk or talk-to prompts as (a) claims, (b) evidence, reasoning, or justification, (c) critique, or (d) other (Table 2). The first three related to key aspects of disciplinary argumentation. The fourth, other, included discussions about definitions, relationships among properties, or reviewing prior investigations (science); and instances of comparing fractions not in the main task (mathematics).

RQ3 asks about the range of ways that PSTs in our study encouraged student-to-student talk. To answer this question, first, we calculated the minimum, maximum, mean, and standard deviation of the number of prompts used per PST for each category—direct encouragement, indirect encouragement, and likely discouragement—and code. Second, for each PST, we compared the number of prompts the PST used that directly encouraged, indirectly encouraged, or that likely discouraged student-to-student talk to the average for that category. We then created a quadrant diagram that located each PST in one of four quadrants (1) high direct encouragement (i.e., a higher-than-average number of prompts that directly encouraged student-to-student talk) and low discouragement (i.e., a lower-than-average number of prompts that discouraged student-to-student talk); (2) high direct

encouragement and high discouragement; (3) low direct encouragement and low discouragement; and (4) low direct encouragement and high discouragement. We provided additional information in each quadrant regarding indirect encouragement prompts and prompts that encouraged disciplinary argumentation.

5 | FINDINGS

Our study findings are organized by the three research questions. We begin by sharing the frequencies with which PSTs used prompts that directly and indirectly encouraged and likely discouraged student talk (Table 3). We conclude by sharing excerpts from three PSTs to provide in-context examples of the prompts and represent the range of PSTs' use of these prompts.

5.1 | RQ1: PSTs' encouragement of student-to-student talk

Most PSTs used one or more prompts that directly encouraged student-to-student talk (83% of 29 PSTs). The turn-and-talk prompt was used by 72% of the PSTs. Over

TABLE 3 Summary of student-to-student talk categories and codes.

Category	Code	Number (%) of PSTs (<i>n</i> = 29)	Number of instances across PSTs' discussions
Direct encouragement		24 (83%)	65
	Turn-and-talk	21 (72%)	33
	Talk-to request	15 (52%)	32
Indirect encouragement		28 (97%)	201
	Framing	9 (31%)	12
	Tell the class	18 (62%)	56
	Consider others' ideas	26 (90%)	132
Discouragement		24 (83%)	83
	Tell me	22 (76%)	70
	Raise hands	8 (28%)	13

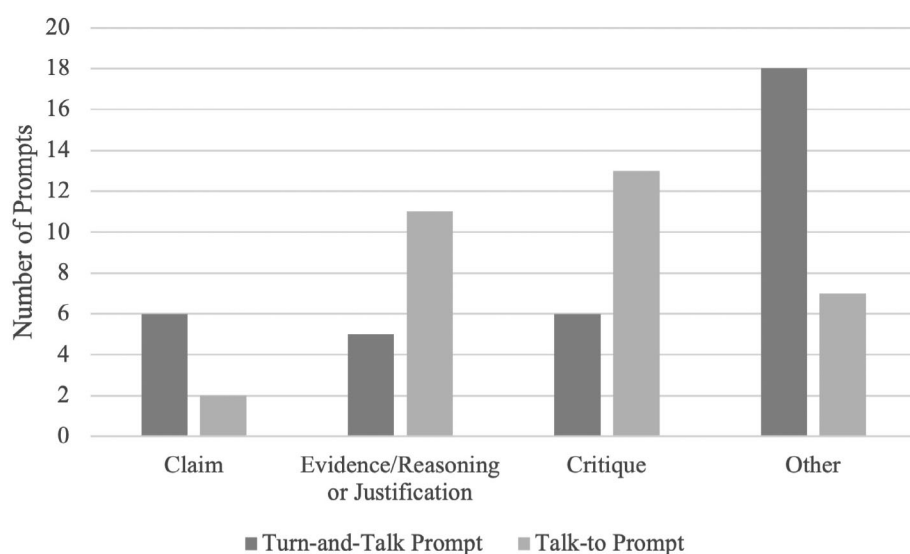


FIGURE 1 Purposes for turn-and-talk and talk-to prompts across PSTs. Two turns were coded as including prompts for claim and evidence/reasoning or justification. Two turns were coded as including prompts for both evidence/reasoning or justification and critique.

half (52%) also used at least one talk-to request—with 21% of the PSTs using just one talk-to request and 31% using two or more. Nearly all PSTs (97%) used prompts that indirectly encouraged student-to-student talk. The most frequently used indirect encouragement was asking students to consider others' ideas (90%). Most participants (62%) prompted students to tell the class about their ideas. Nearly one third (31%) began their discussions with a framing statement.

Figure 1 depicts the frequency with which we applied the argumentation purpose codes to turn-and-talk and talk-to prompts across all study participants; we applied a total of 68 purpose codes to these prompts; 4 were coded with more than one subcode. The figure suggests that talk-to prompts were often used to elicit students' evidence, reasoning, or justification, or engage students in critique. Turn-and-talks were often used for purposes we coded as other; they were used less

often to encourage argument critique. Of the 24 PSTs who used turn-and-talk prompts or talk-to prompts, 17% did to elicit claims, 50% did so to elicit evidence/reasoning or justification, 46% did so to encourage critique, and 67% did so for other reasons. Overall, 71% used at least one turn-and-talk or talk-to prompt to encourage student-to-student talk and disciplinary argumentation.

5.2 | RQ2: PSTs' discouragement of student-to-student talk

Most PSTs (83%) used prompts that likely discouraged student-to-student talk. We applied the code, tell me, to prompts by about three quarters of PSTs (76%). Slightly more than a quarter (28%) of the PSTs asked students to raise hands or not blurt out.

TABLE 4 Student-to-student talk categories and codes per PST.

Category/code	Min prompts per PST	Max prompts per PST	Mean prompts across PSTs	Standard deviation
Direct encouragement	0	8	2.2	2.1
Turn-and-talk	0	5	1.1	1.2
Talk-to request	0	6	1.1	1.5
Indirect encouragement	0	19	6.9	4.5
Framing	0	4	0.4	0.8
Tell the class	0	9	1.9	2.5
Consider others' ideas	0	11	4.6	2.8
Discouragement	0	8	2.9	2.5
Tell me	0	7	2.4	2.3
Raise hands	0	3	0.4	0.8

5.3 | RQ3: Comparing prompts across PSTs

Table 4 summarizes descriptive data for the direct encouragement, indirect encouragement, and discouragement categories and codes per PST. With respect to the major categories, across the 29 PSTs, each PST used between zero and eight prompts that directly encouraged student-to-student talk, with an average of 2.2 prompts per PST (SD 2.1). The range was the same for PSTs' use of prompts that likely discouraged student-to-student talk (M 2.9, SD 2.5). The range of indirect encouragement prompts was between zero and 19 prompts per PST, and the average use per PST (M 6.9, SD 4.5) was larger in comparison to PSTs' use of prompts that directly encouraged or likely discouraged student-to-student talk.

Figure 2 situates each PST into one of four quadrants with respect to their use of prompts that directly encouraged or likely discouraged student-to-student talk. Within each quadrant, we also provide information about their use of indirect encouragement prompts. Just four PSTs (14% of 29) were in Quadrant 1. This is the quadrant that is most aligned with strategies that support student-to-student talk. All four PSTs in this quadrant used a higher-than-average number of direct encouraging prompts (i.e., higher than 2.2, which we interpreted as three or more such prompts) and lower-than-average number of discouraging prompts (i.e., lower than 2.9, which we interpreted as two or fewer such prompts). Two of the four PSTs, Ava and Erin also used a higher-than-average number of indirect encouragement prompts (i.e., higher than 6.9, which we interpreted as seven or more such prompts). (Note: All names are pseudonyms.) Two others, Nicholas and Vaani, used a lower-than-average number of indirect encouragement prompts (i.e., six or fewer prompts). In contrast to Quadrant 1, Quadrant 3 includes nine PSTs (31%) who have the

most room for improving their support of student-to-student talk, and those in Quadrants 2 and 4 had areas of strength and opportunities for growth. Figure 2 also shows in brackets the number of turn-and-talk or talk-to prompts each PST used to encourage disciplinary argumentation. In general, PSTs who used more prompts to directly encourage student-to-student talk also used more prompts to encourage disciplinary argumentation.

Having had experience in simulated classrooms like Mursion® prior to the present study did not seem to be correlated to the quadrant in which the PSTs were placed in Figure 2. The five PSTs (17% of 29 PSTs) who reported having three or more prior experiences in simulated classrooms were distributed evenly across the quadrants, as were the seven PSTs (24%) who reported having one or two prior experiences. The remainder of the PSTs (59%) with no prior experience appeared in each quadrant with many in the more populated Quadrants 3 and 4.

5.4 | Three PSTs

In what follows, we provide examples of three PSTs, Haley, Willow, and Erin, who represent different quadrants in Figure 2 (Quadrants 3, 2, and 1, respectively). All three had a higher-than-average number of indirect encouragement prompts. Haley and Erin facilitated a science discussion; Willow facilitated a mathematics discussion. Haley and Willow reported having no prior experience in a simulated classroom; Erin reporting having had one or two.

5.4.1 | Haley

Haley began her discussion by using framing statements to encourage student-to-student talk and indicating that

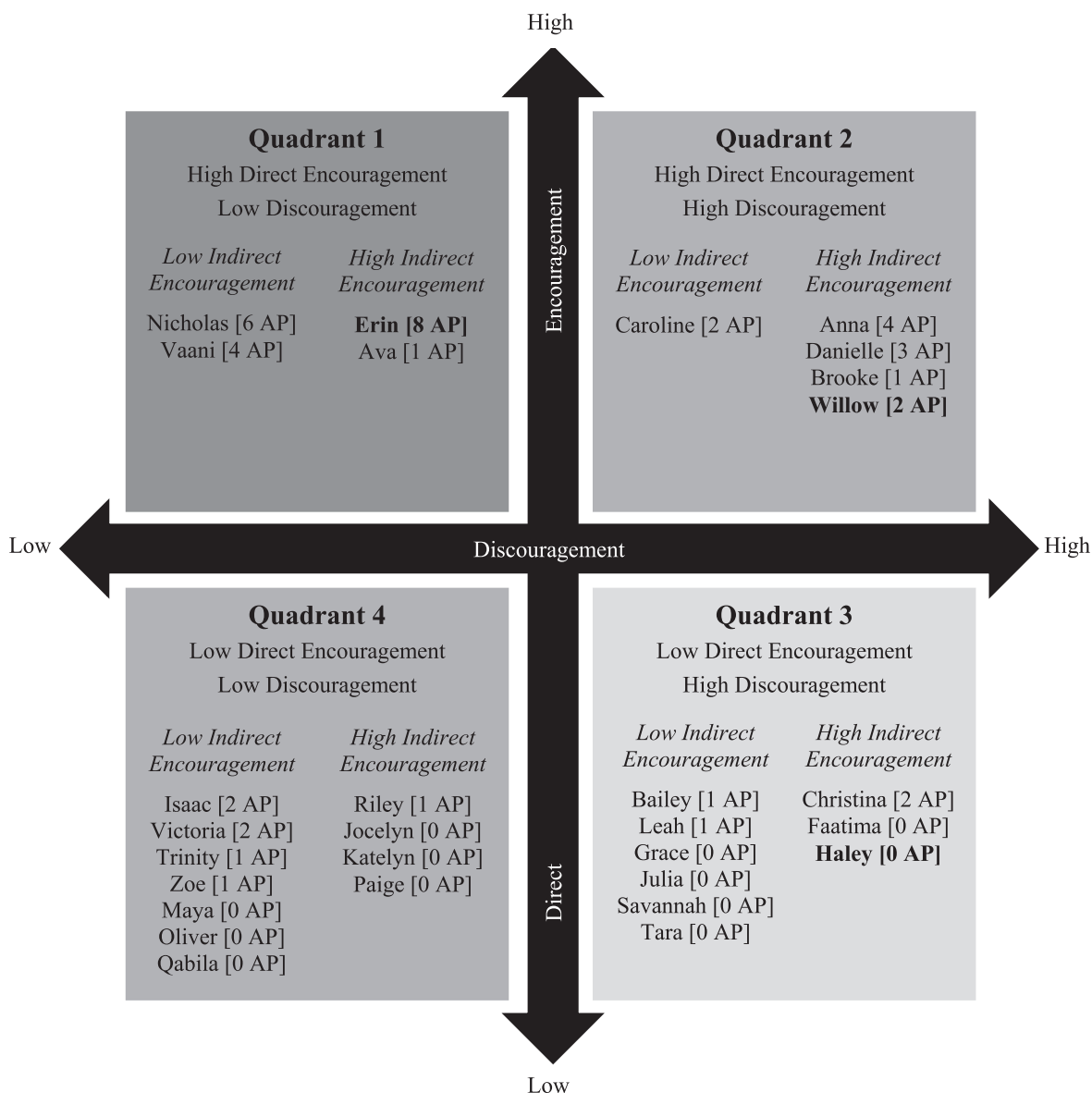


FIGURE 2 Use of prompts across all PSTs. Quadrant 1 represents the most support for student-to-student talk; Quadrant 3 the least; and Quadrants 2 and 4 in between. PSTs featured in findings section shown in bold. “AP” stands for Argumentation Purpose and the number preceding it is how many prompts (turn-and-talk or talk-to prompts) the PST used that encouraged students to either share their arguments or critique others’ arguments.

raising hands was preferable. (Note: Codes are in parentheses).

Haley: We’re going to start by having each group share what they found ... and while we are sharing, we’re going to make sure that we’re using evidence and reasoning and data to back up our arguments. And feel free to ask questions and agree or disagree with one another. (framing)

Jayla:

You mean we don’t have to raise our hands, right? Because this is a discussion. If you could, I would like you to raise your hand because we’re still going to respect when others are speaking, and we want to raise our hand so we don’t interrupt others ... (raise hands) So if you don’t call on us, you want us to raise our hands to answer a question?

Haley:

Mina:

Haley: Yeah. I would like you to share your thoughts and what you're thinking, as well as comment and either agree or disagree with other students as they're sharing as well. (raise hands, framing)

The first framing statement was encouraging with respect to student-to-student talk, yet subsequent prompts may have discouraged student-to-student talk. Haley also used six tell-me prompts in her discussion, which likely discouraged student-to-student talk. For example, Haley asked Mina: "What do you think volume means? Could you tell me a definition?"

Throughout Haley's discussion, she used only one direct encouragement prompt, a turn-and-talk. Haley asked, "I'd like you to turn to your neighbors and talk with them about which property [volume or weight] you think is more important for our investigation." We assigned the code, other, to this prompt because it did not promote disciplinary argumentation (i.e., construction or critique) related to the task.

The next excerpt reveals one of two instances where Haley used a tell-the-class prompt and one of eight instances in which she prompted students to consider others' ideas. Both are indirect encouragement prompt types. Overall, Haley used the second highest number of these prompts ($n = 14$) across all the PSTs (across all PSTs, $M 6.9$; $SD 4.5$).

Haley: Jayla, I liked that you mentioned that we know that the sugar is still there. Can you tell us a little bit more about what you mean by that? (tell the class)

Jayla: Well, yeah. So the sugar is still there because it didn't disappear, it just dissolved ... You just can't see it anymore, but you can still taste it.

Haley: So how does this idea come back to our initial question of if the amount of matter changed when we mixed the ingredients together? ... Does that change any of our thinking or answers? (consider others' ideas)

5.4.2 | Willow

Willow began her discussion by having students review Emily's one less method and explain their understanding to the class in their own words. She did not use framing statements to encourage student-to-student talk. Willow used three direct encouragement prompts. One of these was a turn-and-talk for students to discuss what fractions they could find between three-fourths and 89-ninetieths; we coded the purpose of this prompt as other. Willow used two talk-to prompts, which did not result in student-to-student talk. One of these occurred at the end of the discussion when Willow asked: "Okay. Does anyone else have any questions for each other?" We coded this purpose as critique. The other occurred within the following exchange, which also features several of the 12 indirect encouragement prompts that Willow used in her discussion.

Willow: Does anyone want to talk about the importance of the fraction number line? Explain to your peers whether it is helpful or not helpful. (tell the class)

Mina: So I think that the fraction number line is really important because it also shows you one less fractions that are not in between two-thirds and seven-eighths ...

Willow: Okay. Carlos, what do you think about what Mina just said? Do you agree? Do you disagree? (consider others' ideas)

Carlos: Yeah, I think that the number line is helpful, but I also think that Emily's method is really helpful as well ...

Willow: Okay. Will, what do you think about that? Will, do you have anything to say about that? (consider others' ideas)

Will: Yeah ... But Carlos, what if the teacher asked us to find five fractions in between two-thirds and seven-eighths? Then we would be stuck and then we would have to think of a whole other method to help find the fifth fraction.

- Willow:** Carlos, do you have anything to say back to Will about what he just said? (talk-to request; purpose = encouraging critique)
- Carlos:** Yeah, I see your point. But the method is so quick and easy ...

Willow used three tell-me prompts that may have discouraged student-to-student talk. For example, she asked students to “describe to me” fractions between two thirds and seven eighths.

5.4.3 | Erin

Erin used more direct encouragement prompts, eight, than any other PST in our study. Of these prompts, Erin employed three talk-to prompts that were not followed by student-to-student talk, three talk-to prompts that were followed by student-to-student talk, and two turn-and-talks. The purposes of these eight direct encouragement prompts included eliciting claims (one prompt), eliciting evidence or reasoning (two prompts), critiquing arguments (four prompts, including one also coded as eliciting evidence or reasoning), and a one prompt that we coded as other regarding the definition of matter.

Erin's talk-to prompts were initially not responded to with back-and-forth student-to-student talk. This may have been due to Erin jumping in after the first student responded to her prompt or due to sim error, i.e., the sim not following Erin's lead; our data do not provide clarity with respect to the cause. Her first attempt was when she asked Jayla if she could “share with Carlos and Mina what you found similar ... or different” in her investigation, which we coded as having a purpose of critique. Erin tried two more talk-to prompts that were unsuccessful within a few minutes of her first attempt. Shortly thereafter, her fourth talk-to prompt was successful.

- Erin:** Okay. Does anybody have any other questions for other groups about their investigation? (talk-to prompt #4, purpose = critique)
- Mina:** So why did you measure or why did you weigh the ingredients after you mixed them together? You could have just looked at the pattern from the other investigations. (student-to-student talk, turn #1)

- Jayla:** I just wanted to make sure, because this one was a little different than the other investigations ... So I needed to make sure that the weight didn't change. (student-to-student talk, turn #2)

Mina and Jayla continued talking for three more turns (Mina, Jayla, Mina). Two more talk-to prompts that Erin used also resulted in student-to-student talk. This example demonstrates how Erin persevered and continued to encourage student-to-student talk using talk-to prompts. Erin had the highest number of instances of back-and-forth student talk after talk-to prompts than any other PST in the study.

One of the two turn-and-talks Erin used was toward the end of the discussion to determine if a consensus had been reached. She said, “Let's have one more turn and talk with your neighbors and discuss whether or not matter was conserved in our investigation.”

The indirect encouragement that Erin used took the form of one framing statement, seven instances of asking students to tell the class, and five instances in which students were asked to consider others' ideas. After sharing the discussion goal, Erin provided the following framing statement: “Now, remember when we have our discussion, it is okay to agree or disagree with your classmates and defend your argument and use your evidence as support. Does that sound okay?” The first tell-the-class prompt was early in the discussion when Erin asked: “Now, Will and Emily, can you state your group's claim to the class and share what evidence you collected in your investigation?” The first time Erin asked students to consider others' ideas was when Erin asked: “Jayla, do you agree or disagree with Will and Emily's observations?”

Finally, Erin used just one likely discouraging prompt, tell me, toward the end of the discussion that potentially discouraged student-to-student talk. While summarizing the consensus the students had reached, Erin stated: “Now, can anybody else tell me why we use weight?”

6 | DISCUSSION AND IMPLICATIONS

In this study, we explored how PSTs encouraged and discouraged student-to-student talk within the context of a mathematics or science argumentation-focused discussion in a simulated classroom environment, contributing

to the literature about the specific prompts PSTs use to facilitate student-to-student talk (Davis et al., 2006; Davis & Palincsar, 2022). In what follows, we share key takeaways from our study's findings and embed ideas for future research and implications for TEs throughout.

Across the PSTs, we found variation in their use of prompts that directly encouraged, indirectly encouraged, and likely discouraged student-to-student talk while facilitating a mathematics or science argumentation-focused discussion. Most of the PSTs in our study were successful at encouraging student-to-student talk by using at least one turn-and-talk prompt, and some were able to also use one or more direct talk-to prompts. We believe that turn-and-talk prompts were more commonly used by the PSTs, as this discourse strategy was discussed in all four TEs' mathematics and science methods courses, whereas talk-to prompts were only emphasized by two TEs. Given this, most of the PSTs were just beginning to implement strategies related to the social constructivist approach to learning (Palincsar, 1998; Vygotsky, 1978), as they used on average two prompts to encourage student-to-student talk. This finding is contrary to previous research studies that found PSTs were unable to facilitate student-to-student talk (Bofferding & Kemmerle, 2015; Davis & Palincsar, 2022; Haverly et al., 2020; Murphy, 2016). It is important to note that these previous studies took place in regular classroom settings. This could suggest the simulated classroom environment provided PSTs a space where they could try implementing the student-to-student talk strategies they were learning in their mathematics and science methods courses (Mikeska & Howell, 2020; Lottero-Perdue et al., 2022). Thus, TEs may want to consider providing opportunities for PSTs to practice facilitating student-to-student talk within a simulated classroom or using other approximations of practice (Grossman et al., 2009) before trying to implement this skill in the regular classroom. It is critical for future research to investigate if simulated approximations help PSTs transfer the strategies for facilitating student-to-student talk into the regular classroom.

Comparing direct requests to encourage student-to-student talk, talk-to prompts more often encouraged disciplinary argumentation when compared with turn-and-talk prompts, which were primarily used for other purposes outside the scope of disciplinary argumentation. PSTs who used talk-to prompts to encourage student-to-student talk also used more of these prompts to encourage argument construction and critique. These findings suggest to TEs that they should encourage PSTs to use more direct talk-to prompts to support argument construction and critique, and to continue to use turn-and-talk requests, albeit with an increased focus on disciplinary argumentation. This encouragement

would include sharing examples of talk-to requests and turn-and-talk requests that have this focus. Figure A2, Appendix includes sample direct prompts to encourage student-to-student talk during an argumentation discussion. Methods instruction could also involve having PSTs examine videos or transcripts of their own argumentation discussions from simulations and other approximations, reflect on how they used prompts that either encouraged or discouraged student-to-student talk, and consider how they might rewrite those prompts to be more encouraging and less discouraging (Lottero-Perdue et al., 2022).

Most PSTs used multiple indirect prompts to encourage students to consider others' ideas or tell the class their own ideas. These types of prompts are in alignment with Chapin et al. (2013) and Michaels and O'Connor's (2012) talk moves which inspire students to think with others. That said, these prompts did not result in back-and-forth student-to-student talk occurring. Thus, these findings demonstrate that, apart from the turn-and-talk talk move, just employing talk moves does not encourage student-to-student talk. Rather, PSTs need to persist like Erin did in using more direct prompts that explicitly ask students to respond to each other (Lottero-Perdue et al., 2022; Windschitl et al., 2020). With some modification, the indirect prompts PSTs are using could easily be turned into direct prompts that are more likely to elicit student-to-student talk. For example, "What do you think about what Jayla just shared?" could be shifted to "Emily, could you talk with Jayla about what she just shared? And Jayla, be sure to respond back to Emily." Therefore, TEs should consider building upon frameworks, such as talk moves, to help PSTs modify their prompts to directly encourage students to talk to each other. By doing so, students will likely engage more deeply with each other throughout an argumentation discussion.

Finally, PSTs were equally likely to discourage student-to-student talk as encourage it by using prompts such as the tell-me prompt. This prompt reinforces the cultural norm of schooling in which students talk to the teacher, not other students. Thus, there were instances where the PSTs were still implementing the IRE approach (Cazden, 2002; Lemke, 1990) rather than an approach like FLE (Lloyd et al., 2016), which aligns with social constructivism (Palincsar, 1998; Vygotsky, 1978). These findings are not surprising given this was the PSTs' first experience facilitating student-to-student talk within the context of a disciplinary argumentation discussion. When learning a new high-leverage practice, it is easy to resort back to what is familiar in the moment, as the IRE is less challenging for teachers to navigate (Davis & Palincsar, 2022). Furthermore, these results may suggest that PSTs can be more focused on eliciting students' ideas in a teacher-directed

manner during the discussion than on engaging the students in the discussion skill of student-to-student talk. While eliciting students' ideas is certainly an important pedagogical skill, it is not enough to effectively engage students in mathematics or science argumentation-focused discussions. An implication from this is that TEs may want to consider providing additional opportunities for PSTs to practice facilitating student-to-student talk in multiple settings (Cartwright, 2012). It would be helpful for researchers to explore other settings and tools that would help PSTs improve their encouragement of student-to-student talk.

7 | LIMITATIONS

There are four primary limitations of this study. The first is that while we explored 29 PSTs' support for student-to-student-talk, we cannot claim generalizability to all PSTs in methods courses. Second, since we only examined this subset of PSTs and did not have a comparison group, we are limited to describing the range of performance across these PSTs rather than, for example, how they performed against expert teachers. Indeed, it would be fascinating to explore the prompts that expert teachers use to support student-to-student talk in the simulated classroom environment. A third limitation concerns the sims who played the students during the simulation. Although they received extensive training to respond consistently as the student avatars, the high cognitive demand of their role and human error may have led to them missing cues for student-to-student talk. Finally, we are unable to report if the prompts PSTs used to foster student talk in the simulation would be similar to those they would use in real classrooms, and relatedly, cannot discount the possibility that PSTs' performance in the simulator might differ from the real classroom for a variety of reasons, such as higher cognitive load in the real classroom or anxiety about using a simulation.

8 | CONCLUSION

Findings from this study demonstrate that PSTs can align some of their discourse practices with the recommendations of the recent reforms and provide opportunities for student-to-student talk within the context of an argumentation-focused discussion. PSTs would benefit from a broader array of talk moves (Chapin et al., 2013; Michaels & O'Connor, 2012) that include direct encouragement prompts, such as talk-to prompts, to encourage student-to-student talk; these prompts were the only ones in our study that resulted in discernable back-and-forth

talk. Variation across the PSTs in our study demonstrates what is possible and areas for improvement. With increased practice, we suspect that more PSTs would join Erin and others in Quadrant 1, using multiple direct prompts to encourage student-to-student talk and limiting their use of prompts that might discourage such talk. When teachers intentionally incorporate opportunities for students to engage in sense-making discussions with each other, meaningful learning will occur for all students which is the goal of both mathematics and science education.

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REFERENCES

- Benedict-Chambers, A. (2016). Using tools to promote novice teacher noticing of science teaching practices in post-rehearsal discussions. *Teaching and Teacher Education*, 59, 28–44.
- Boerst, T., Sleep, L., Ball, D., & Bass, H. (2011). Preparing teachers to lead mathematics discussions. *Teachers College Record*, 113(12), 2844–2877.
- Bofferding, L., & Kemmerle, M. (2015). Elementary teacher candidates' use of number strings: Creating a math-talk learning community. *Mathematics Teacher Educator*, 3(2), 99–115.
- Bondie, R., Mancenido, Z., & Dede, C. (2021). Interaction principles for digital puppeteering to promote teacher learning. *Journal of Research on Technology in Education*, 53(1), 107–123.
- Cartier, J. L., Smith, M. S., Stein, M. K., & Ross, D. K. (2013). *5 practices for orchestrating productive task-based discussions in science*. National Council of Teachers of Mathematics.
- Cartwright, T. J. (2012). Science talk: Preservice teacher facilitating science learning in diverse afterschool environments. *School Science and Mathematics*, 112(6), 384–391.
- Cazden, C. B. (2002). *Classroom discourse: The language of teaching and learning* (2nd ed.). Heinemann.
- Chapin, S. H., O'Connor, M. C., Anderson, N. C., & Chapin, S. H. (2013). *Classroom discussions in math: A teacher's guide for using talk moves to support the common core and more, grades K–6* (3rd ed.). Math Solutions.
- Cobb, P., & Yackel, E. (1998). A constructivist perspective on the culture of the mathematics classroom. In F. Seeger, J. Voigt, & U. Waschescio (Eds.), *The culture of the mathematics classroom: Analysis and changes* (pp. 158–190). New York: Cambridge University Press.

- Codreanu, E., Huber, S., Reinhold, S., Sommerhoff, D., Neuhaus, B. J., Schmidmaier, R., Ufer, S., & Seidel, T. (2022). Diagnosing mathematical argumentation skills: A video-based simulation for pre-service teachers. In F. Fischer & A. Opitz (Eds.), *Learning to diagnose with simulations: Examples from teacher education and medical education* (pp. 33–47). Springer.
- Confrey, J., & Kazak, S. (2006). A thirty-year reflection on constructivism in mathematics education in PME. In *Handbook of research on the psychology of mathematics education* (pp. 305–345). Brill.
- Davis, E. A., & Palincsar, A. S. (2022). Engagement in high-leverage science teaching practices among novice elementary teachers. *Science Education*, 107, 291–332.
- Davis, E. A., Petish, D., & Smithey, J. (2006). Challenges new science teachers face. *Review of Educational Research*, 76(4), 607–651.
- Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education*, 84, 287–312.
- Edmondson, E., & Choudhry, F. (2018). Talking the talk: Exploring teacher learning and their use of discourse strategies. *School Science and Mathematics*, 118(7), 273–289.
- Ellis, A. B. (2011). Generalizing-promoting actions: How classroom collaborations can support students' mathematical generalizations. *Journal for Research in Mathematics Education*, 42, 308–345.
- Ghousseini, H. (2015). Core practices and problems of practice in learning to lead classroom discussions. *The Elementary School Journal*, 115(3), 334–357.
- Grossman, P., Hammerness, K., & McDonald, M. (2009). Redefining teaching, re-imagining teacher education. *Teachers and Teaching: Theory and Practice*, 15(2), 273–289.
- Haverly, C., Calabrese Barton, A., Schwarz, C. V., & Braaten, M. (2020). Making space: How novice teachers create opportunities for equitable sense-making in elementary science. *Journal of Teacher Education*, 71(1), 63–79.
- Howell, H., Mikeska, J. N., Tierney, J., Baehr, B., & Lehman, P. (2021). *Conceptualizing and development of a performance task for assessment and building elementary preservice teachers' ability to facilitate argumentation-focused discussions in mathematics: The ordering fractions task*. ETS Research Memorandum. ETS.
- Jiménez-Aleixandre, M. P., & Erduran, S. (2008). *Argumentation in science education. Perspectives from classroom-based research*. Springer.
- Johnson, L. L., & Kim, G. M. (2021). Experimenting with game-based learning in preservice teacher education. *English Teaching: Practice & Critique*, 20(1), 78–93.
- Kazemi, E., & Stipek, D. (2001). Promoting conceptual thinking in four upper-elementary mathematics classrooms. *Elementary School Journal*, 102, 59–80.
- Kosko, K. W., Ferdig, R. E., & Roche, L. (2021). Editorial: Conceptualizing a shared definition and future directions for extended reality (XR) in teacher education. *Journal of Technology and Teacher Education*, 29(3), 257–278.
- Lampert, M., Franke, M. L., Kazemi, E., Ghousseini, H., Turrou, A. C., Beasley, H., Cunard, A., & Crowe, K. (2013). Keeping it complex using rehearsals to support novice teacher learning of ambitious teaching. *Journal of Teacher Education*, 64(3), 226–243.
- Lemke, J. (1990). *Talking science: Language, learning, and values*. Ablex.
- Lloyd, G. M., & Murphy, P. K. (2023). Mathematical argumentation in small-group discussions of complex mathematical tasks in elementary teacher education settings. In *Mathematical challenges for all* (pp. 169–195). Springer.
- Lloyd, M. H., Kolodziej, N. J., & Brashears, K. M. (2016). Classroom discourse: An essential component in building a classroom community. *School Community Journal*, 26(2), 291–304.
- Lottero-Perdue, P. S., Mikeska, J. N., & Nester, M. S. (2022). Using preservice teachers' transcript coding of simulated argumentation discussions to characterize aspects of their noticing about argument construction and critique. *Contemporary Issues in Technology and Teacher Education*, 22(1), 105–139.
- McNeill, K. L., Katsh-Singer, R., González-Howard, M., & Loper, S. (2016). Factors impacting teachers' argumentation instruction in their science classrooms. *International Journal of Science Education*, 38(12), 2026–2046.
- Melhuish, K., Thanheiser, E., & Guyot, L. (2020). Elementary school teachers' noticing of essential mathematical reasoning forms: Justification and generalization. *Journal of Mathematics Teacher Education*, 23(1), 35–67.
- Michaels, S., & O'Connor, C. (2012). *Talk science primer*. TERC.
- Mikeska, J. N., Howell, H., & Straub, C. (2019). Using performance tasks within simulated environments to assess teachers' ability to engage in coordinated, accumulated, and dynamic (CAD) competencies. *International Journal of Testing*, 19(2), 128–147.
- Mikeska, J. N., & Howell, H. (2020). Simulations as practice-based spaces to support elementary science teachers in learning how to facilitate argumentation-focused science discussions. *Journal of Research in Science Teaching*, 57(9), 1356–1399.
- Mikeska, J. N., Howell, H., Orlandi, E., King, K., Lipari, M., & Simonelli, G. (2021). *Conceptualizing and development of a performance task for assessment and building elementary preservice teachers' ability to facilitate argumentation-focused discussions in science: The S2 conservation of matter task*. ETS Research Memorandum. ETS.
- Mikeska, J. N., Howell, H., & Kinsey, D. (2022). Do simulated teaching experiences impact elementary preservice teachers' ability to facilitate argumentation-focused discussions in mathematics and science? *Journal of Teacher Education*, 74(5), 422–436.
- Murphy, C. (2016). Changing the way to teach maths: Preservice primary teachers' reflections on using exploratory talk in teaching mathematics. *Mathematics Teacher Education and Development*, 18(2), 29–47.
- National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). *Common core state standards for mathematics*. Authors.
- NGSS Lead States. (2013). *Next generation science standards: For states, by states*. The National Academies Press.
- Palincsar, A. S. (1998). Social constructivist perspectives on teaching and learning. *Annual Review of Psychology*, 49, 345–375.
- Rees, C. A. B., & Roth, W. B. (2019). Discourse forms in a classroom transitioning to student-centered scientific inquiry through

- co-teaching. *International Journal of Science Education*, 41(5), 586–606.
- Schreier, M. (2012). *Qualitative content analysis in practice*. Sage.
- Schreier, M. (2014). Qualitative content analysis. In I. U. Flick (Ed.), *The SAGE handbook of qualitative data analysis* (pp. 170–183). Sage.
- Shaughnessy, M., Garcia, N. M., O'Neill, M. K., Selling, S. K., Willis, A. T., Wilkes, C. E., II, Salazar, S. B., & Ball, D. L. (2021). Formatively assessing prospective teachers' skills in leading mathematics discussions. *Educational Studies in Mathematics*, 108, 451–472.
- Smith, M. S., & Stein, M. K. (2018). *5 practices for orchestrating productive mathematics discussion*. National Council of Teachers of Mathematics.
- Staples, M., & Connor, A. (2022). *Conceptions and consequences of mathematical argumentation, justification, and proof*. Springer.
- Stein, M. K., Engle, R., Smith, M., & Hughes, E. (2008). Orchestrating productive mathematical discussions: Five practices for helping teachers move beyond show and tell. *Mathematical Thinking and Learning*, 10(4), 313–340.
- Toulmin, S. (1969). *The uses of argument*. Cambridge University Press.
- Vygotsky, L. S. (1978). In M. Cole, V. John-Steiner, S. Scribner, & E. Souberman (Eds.), *Mind in society: The development of higher psychological processes*. Harvard University Press.
- Windschitl, M., Thompson, J., & Braaten, M. (2020). *Ambitious science teaching*. Harvard Education Press.
- Witherspoon, E., Miller, D., Pinerua, I., & Gerdeman, D. (2022). Mathematical and scientific argumentation in PreK–12: A cross-disciplinary synthesis of recent DRK-12 projects. *American Institutes for Research*.

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APPENDIX

FIGURE A1 Student avatars in the upper elementary Mursion® simulated classroom. Source: Image provided by Mursion®. Used with permission.



- “Do you agree/disagree with ____ [student’s] claim/evidence/reasoning/justification? Tell them if you do and why or why not?”
- “If you agree/disagree with the evidence/reasoning/justification that ____ [student] used to support ____ [student’s] claim, raise your hand. Be ready to tell them why.”
- “Does anyone have questions to ask ____ [student/group] about their claim/evidence/reasoning/justification? Be sure to ask your question directly to that group.”
- “What is your rebuttal in response to what ____ [student/group] shared about their claim/evidence/reasoning/justification? Please share your response with ____ [student/group].”
- “Please share your claim/evidence/reasoning/justification with ____ [student/group].”
- “Try to convince ____ [student/group] your claim is accurate. Be sure to use evidence/reasoning/justification as you try to convince them that you are correct and speak to ____ [student/group] directly.”
- “Can you explain your thinking about your reasoning/justification with ____ [student/group]? And ____ [student/group], please be sure to respond back to them about your thoughts.”
- “Remember that I’d like for you to talk to one another, not just to me, about your claims/evidence/reasoning/justification.”
- “Please talk with one another about whether your claims are different or are the same.”

Other strategies:

- Providing wait time after using a prompt and after a student responds to the prompt.
- Not interrupting students as they talk to one another.

FIGURE A2 Sample prompts that directly encourage student-to-student talk and support disciplinary argumentation. Our use of “claim/evidence/reasoning/justification” implies that any one of those or could be used in the question.