Elementary Preservice Teachers' Noticing of Scientific Argumentation within Two Online Practice Spaces

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Abstract

Scientific argumentation discussions enable students to engage in critical sense-making with their peers about investigations. Facilitating these discussions is challenging for elementary preservice teachers (PSTs). One reason for this is their limited experience noticing how teachers facilitate and students respond within argumentation discussions. We provided opportunities for 28 PSTs in two science methods courses to practice noticing instances where they had encouraged argument construction and critique in discussions they facilitated. The discussions occurred in two online practice spaces that approximate aspects of real classrooms: Eliciting Learner Knowledge (ELK) and Avatar-Based Simulation (ABS). Ten PSTs participated in our study. PSTs noticed a little over half of the researcher-coded argumentation construction instances in both ELK and ABS. PSTs were more likely to notice instances where they elicited students' claims and evidence and less likely to notice when they encouraged students to provide justification. The PSTs noticed roughly two-thirds of the researcher-coded prompts related to argumentation critique. They noticed prompts asking students if they agreed with one another but experienced some difficulty noticing when they asked students to convince others or compare arguments. These findings have important implications for teacher educators who support PSTs with learning how to facilitate argumentation discussions.

Keywords: noticing, argumentation, pre-service teacher education, simulated classroom environments, practice-based teacher education

Introduction

In the current vision for science teaching and learning, students are expected to actively participate with their peers in scientific sense-making to deepen their knowledge of scientific phenomena (National Research Council [NRC], 2012). One widely promoted avenue for doing so involves teachers engaging their students in scientific argumentation. Argumentation is one of the eight scientific and engineering practices outlined in the *Framework for K-12 Science Education* (NRC, 2012) and *Next Generation Science Standards* (NGSS Lead States, 2013) and is a key scientific practice that teachers should include in their instruction. Argumentation allows students to engage in critical sense-making with their peers to reach a consensus about the outcomes from an investigation (NRC, 2012). When students engage in the practice of argumentation, they (1) justify, defend, and revise their claims with evidence and reasoning (i.e., engage in argument construction); and (2) compare, question, and critique the arguments of others (i.e., engage in argument critique) (Berland & Reiser, 2009; McNeill et al., 2006; Mikeska & Howell, 2020).

Engaging students in productive scientific argumentation discussions is an ambitious pedagogical practice for preservice teachers (PSTs) to implement in part because this approach requires them to make in-the-moment instructional decisions (Hammer et al., 2012; van Es & Sherin, 2002). To support PSTs with learning how to respond to student thinking during argumentation discussions, researchers recommend providing opportunities within teacher education programs for PSTs to practice facilitating these discussions in contexts that approximate the realities of a classroom (Grossman et al., 2009). Approximations of practice, such as role-playing, microteaching, and/or teaching rehearsals, are frequently infused into science methods courses to provide opportunities for PSTs to practice implementing the ambitious teaching strategies they are learning (Lampert et al., 2013; Windschitl et al., 2012). While the intentionality of these approximations of practice are certainly noble, PSTs often find it difficult to act as a K-12 student or consider their peers as students. Technologically mediated simulations are emerging as a possible solution to providing classroom spaces where PSTs can practice new instructional moves in a low-risk learning environment where students' learning would not be impacted (Mikeska & Howell, 2020). In this study, we provided opportunities for elementary PSTs to practice aspects of facilitating argumentation discussions in two different online practice spaces designed to approximate interactions with students. These online practice spaces enable PSTs to practice teaching within simulated classroom environments PSTs access through their internet-connected computers (Mikeska et al., 2022).

Another essential component to developing PSTs' abilities to effectively respond to student thinking while facilitating argumentation discussions involves noticing. Noticing includes how PSTs attend to, interpret, and respond to students' ideas while teaching to support student learning (Jacobs et al., 2010; van Es & Sherin, 2002). To support PSTs with actively noticing student thinking while teaching, they need multiple opportunities to analyze videos and/or transcripts of their instruction and notice when and how they prompt and empower students to engage in argument construction and critique (Levin et al., 2009; Windschitl et al., 2011). When engaging in noticing, PSTs should focus on student thinking as well as their own teaching moves (Benedict-Chambers & Aram, 2017). By analyzing instruction with an intentional focus, researchers claim PSTs will be more responsive to student ideas and adapt instruction as the lesson unfolds (Levin et al., 2009; van Es & Sherin, 2002; Sherin & van Es, 2009; Windschitl et al., 2011). However, there is relatively little in the research literature about PSTs' abilities to notice in science (Benedict-Chambers & Aram, 2017; Chan et al., 2021; Luna

& Sherin, 2017; Luna et al., 2018), and more specifically, with respect to argumentation construction and critique after engaging in a simulated classroom environment (Lottero-Perdue et al., 2022).

In this study, the PSTs had opportunities to review their interactions in two simulated practice spaces and reflect on their use of prompts to encourage students' productive engagement in argument construction and critique. Throughout this paper, a prompt is considered a question or statement PSTs make to encourage students' responses. Our main research interest focuses on understanding elementary PSTs' abilities to notice argument construction and critique in the context of online practice spaces designed to provide them with opportunities to build their knowledge and skills for facilitating argumentation discussions. We ask the following research questions:

1. Compared to expert coding by researchers, what prompts do PSTs notice and not notice to encourage argument construction or critique in two online practice spaces?
2. Are there particular types of argument construction or critique prompts that PSTs tend to notice more than others?

Theoretical Framework and Related Literature

Scientific Argumentation

Scientific argumentation is a practice that allows students to construct, defend, compare, critique, and refine their thinking with the goal of reaching a consensus about a natural phenomenon (Berland & Reiser, 2009; McNeill & Krajcik, 2012; NGSS Lead States, 2013; Osborne et al., 2013). Thus, scientific argumentation involves an epistemic structure for constructing a claim and supporting it with evidence and reasoning, and a dialogic process where students persuade and critique arguments shared (Jimenez-Aleixandre & Erduran, 2008; McNeill et al., 2016). An epistemic structure commonly used by teachers and students is the claim-evidence-reasoning (CER) framework (McNeill et al., 2006). Claims answer the investigable question, evidence consists of qualitative and quantitative data that support the claim, and reasoning justifies the claim and evidence by making a connection to a scientific principle. We refer to the work that students engage in to construct, justify, and revise scientific claims and evidence-based reasoning as argument construction (McNeill et al., 2016). Once students formulate a high-quality scientific argument, they then engage in the dialogic component where they persuade others to agree with their argument and critique the arguments of other students. We refer to this component of scientific argumentation as argument critique (McNeill et al., 2016). Argument critique may involve students questioning, comparing arguments, and agreeing and disagreeing with one another.

Talk moves are a useful tool to provide beginning teachers who are learning to facilitate discussions (Michaels & O'Connor, 2012). Examples of talk moves to support argumentation construction include: "What evidence do you have that the amount of matter would be the same?" and "What do you think is the reason the amount of matter stays the same?" A talk move that can be used to facilitate argumentation critique is "Do you agree/disagree with what was shared? Why or why not?" While these talk moves are helpful when beginning teachers are just learning to facilitate discussions, it is important that teacher educators explain that these moves are merely examples of strategies they could use to navigate scientific argumentation discussions (Reigh & Osborne, 2021). To help PSTs learn to purposefully respond to student thinking while engaging in scientific argumentation, it is important that they engage in noticing tasks that allow them to identify talk moves that deepen students' sensemaking. Doing so provides a way to broaden PSTs' knowledge about teaching moves they could use to support argument construction and critique in their interactions with students. Therefore, in this study, the PSTs analyzed transcripts and/or videos from their engagement in two simulated practice spaces to notice prompts they used to support students with argument construction and argument critique.

Very few studies have explored how PSTs implement scientific argumentation in the classroom setting (Mikeska & Howell, 2020). As a result, little is known about the ways in which PSTs engage learners in this ambitious science teaching practice and what supports equip PSTs with the pedagogical knowledge and skills for how to implement this practice. Furthermore, studies that explored PSTs' knowledge and skills with respect to argumentation are discovering mixed results (Katluca & Aydin, 2017; Mikeska & Howell, 2020; Sadler, 2006). Mikeska and Howell (2020) explored how PSTs engaged five avatars in argumentation construction and critique in a simulated classroom environment. Based on the findings from this study, PSTs were more likely to facilitate argumentation construction and less likely to engage learners in argumentation critique. Sadler (2006) investigated the ways in which secondary science PSTs enacted argumentation instruction after learning about this practice in their science methods course. Findings from this study showed the PSTs were able to incorporate counterarguments and rebuttals in their instruction. On the contrary, Katluca and Aydin (2017) discovered that the PSTs in their study found value in the practice of argumentation; however, they believed the implementation of this practice would be more teacher-directed rather than engaging the learners in the sense-making process collectively. Given the variation in these studies' findings, it is apparent that additional research is needed to explore what learning experiences help PSTs learn to facilitate scientific argumentation discussions in the classroom setting. In this study, we explored PSTs' ability to notice when they were engaging learners in argumentation construction and critique, as researchers claim this can support PSTs who are learning to navigate and respond to student thinking during argumentation discussions (Mikeska & Howell, 2020; van Es & Sherin, 2002; Windschitl et al., 2011).

Noticing

To grow in the ambitious teaching practice of facilitating argumentation discussions, teachers need to develop the pedagogical skill of noticing (van Es, 2011). Noticing involves:

> a) identifying what is important or noteworthy about a classroom situation; b) making connections between the specifics of classroom interactions and the broader principles of teaching and learning they represent; and c) using what one knows about the context to reason about classroom interactions. (van Es & Sherin, 2002, p. 573)

When teachers learn to notice, they are more responsive to students' ideas in the moment of teaching (Hammer et al., 2012; Levin et al., 2009; Sherin & van Es, 2009; van Es, 2011). Given the benefits of PSTs learning to notice, scholars have advocated that teacher education programs should prioritize opportunities for PSTs to systematically analyze instruction to help improve their responsive teaching practices (Sherin & van Es, 2005; Talanquer et al., 2013). These learning experiences should include training on what and how to notice and opportunities to apply these skills to analyze their own practice (van Es & Sherin, 2002).

Noticing is an ambitious practice (Ball, 2011). Information abounds in the classroom, and it is difficult for teachers, especially novices, to begin the noticing process by identifying the most salient classroom interactions (Abell et al., 1998; Dalvi & Wendell, 2017; Jacobs et al., 2010; Star and Strickland, 2008; Talanquer et al., 2013). Rather PSTs tend to notice instances of classroom management (Star & Strickland, 2008), how they look or sound in the lesson (Rosaen et al., 2008), student excitement during the investigation (Abell et al., 1998), or general ideas about what students think rather than specific details (Erickson, 2011). These studies show that

PSTs need more support for how to attend to and interpret instances connected to larger educational principles, such as scientific argumentation. Without the ability to identify interactions that connect to larger educational principles, the third part of noticing—using what was noticed and considering contextual variables to inform future instruction—is not possible.

There is evidence from the literature that, like other practices, noticing can be rehearsed and improved through various strategies in teacher education. Previous research has explored PSTs' ability to notice when analyzing: student work (Luna et al., 2018); videos of other teachers' practice (Abell & Cennamo, 2003; Chan et al., 2021; Gaudin & Caliès, 2015; Mitchell & Marin, 2015; Star & Strickland, 2008; Seidel et al., 2011; Talanquer et al., 2013); or videos of their own instruction after engaging in a teaching rehearsal (Benedict-Chambers & Aram, 2017) or implementing a lesson (Barnhart & van Es, 2015; Rosaen et al., 2008; Seidel et al., 2011). A benefit of video analysis is that videos can be paused and analyzed (van Es & Sherin, 2002). Noticing may occur verbally among teachers, as in discussions that occur around video analysis within video book clubs (e.g., Gonzalez & Vargas, 2020; Luna and Sherin, 2017).

Tools and frameworks can be used to further support PSTs' noticing when analyzing videos, transcripts, or student work (Barnhart & van Es, 2015; Benedict-Chambers, 2016; Benedict-Chambers & Aram, 2017; van Es & Sherin, 2002). When PSTs receive additional guidance in what to notice, researchers found they attend to the more critical aspects of science teaching and learning that result in student sense-making as outlined in recent reform documents (Barnhart & van Es, 2015; Benedict-Chambers, 2016; Benedict-Chambers & Aram, 2017; Dalvi & Hoffman, 2019; NGSS Lead States, 2013; NRC, 2012). Thus, tools and frameworks can help PSTs focus on van Es and Sherin's (2002) elements of connecting salient interactions (part a) to educational principles (part b) while annotating videos or coding video transcripts (Lottero-

Perdue et al., 2022; McFadden et al., 2014; Mitchell & Marin, 2015; Tripp & Rich, 2012). In this way, the salient interactions are represented by the video segments or transcripts that teachers identify and annotate or code with respect to educational actions and principles.

One recent study, which includes two co-authors (Lottero-Perdue et al., 2022), examined PSTs' noticing of argumentation within one simulated classroom environment, Mursion ®. Nineteen PSTs in the first author's class were asked to code another teacher's discussion transcript for how the teacher prompted argument construction and critique. The PSTs then facilitated the same discussion in the simulated classroom and then coded their own transcripts for prompts they used to engage students in argument construction and critique. Findings from the study suggested that PSTs identified the majority of prompts used to encourage argument construction and argument critique. However, the PSTs often did not notice prompts that encouraged students to share their reasoning and sometimes identified non-examples of argument construction and critique, suggesting that their ideas about these principles as enacted through prompts may be overly broad. Further, the study found unique value in coding both someone else's and their own transcripts.

In what follows, we describe the present study, which extends the work done in the Lottero-Perdue et al. (2022) study in two ways. First, the present study examines PST noticing across two different online practice spaces. Second, PSTs from two different science methods courses at two institutions participated in the present study.

Study Design

This study is part of a larger NSF-funded research project that investigates how online practice spaces can be used within science and mathematics methods courses to scaffold PSTs as they learn to facilitate argumentation discussions. In this section, we briefly describe the study participants, the two practice spaces we examined for this study, and our data sources and analytical methods.

Participants

In spring 2021, 28 elementary PSTs (all third-year students) were enrolled in two science methods courses taught by two of the co-authors from different institutions, Institution A and Institution B. We received consent and complete data for 10 PSTs, four from Institution A and six from Institution B. Nine participants identified as female and one identified as male; all identified as White/Caucasian. Six participants are pursuing a major in elementary education with a minor in science education (Institution B); four a major in integrated elementary and special education (Institution A).

Practice Spaces

Practice Space 1: Eliciting Learner Knowledge (ELK)

This practice space involves pairs of PSTs engaging in a 7-minute typed chat on the online ELK platform (Wang et al., 2021). During the chat, one PST plays the role of the teacher and the other plays the role of a student. The ELK platform provides each PST with specific information pertinent to their role prior to starting the chat. The PST in the teacher role is reminded that their job is to elicit the student's understanding about the topic and does not receive any information about the student's ideas. The PST in the student role is given information about what the student they are playing understands about a topic and are told that they should answer closed-ended questions with short answers.

In this study, the ELK chat focused on eliciting student knowledge about conservation of matter for two investigations in which the students had previously engaged. In one investigation, "Freezing Water," the class explored what happened to the amount of matter when water in a plastic bottle was frozen. In the other investigation, “Changing Paper,” the class observed what happened to the amount of matter when the same piece of paper takes three different shapes—its original flat form, balled up, and ripped into pieces. Just as in a real classroom, students may make sense of these investigations differently upon reflecting on them. There are two student roles in ELK, Charlie and Dana. When paired with Charlie, the PST has the opportunity to learn that Charlie thinks matter was not conserved because the volume and shape of the water and paper changed. In a chat with Dana, the PST has the opportunity to learn that Dana thinks matter was conserved since the weight of the water and paper did not change. See Figure 1 for an example of an ELK chat between two PSTs; one plays the teacher and the other plays Charlie.

Figure 1

ELK Chat Example

Teacher:	Do you think the matter was conserved or changed in both of the investigations with paper and water?
Charlie:	I think that the amount of matter increased.
Teacher:	Can you tell me more about why you think the amount of matter was conserved in both the water and paper investigations? Can you tell me more about why you think the amount of matter increased?
Charlie:	Well the balled up paper takes up more space than the flat paper.
Teacher:	So what you are saying is that because the balled up paper takes up more space than the flat paper, the amount of matter increases?
Charlie:	Yes, it takes up more space so there is more matter.
Teacher:	How did you arrive at that conclusion?
Charlie:	Since the balled-up paper is bigger than the flat paper it takes up more space
Teacher:	Why does the amount of space something takes up change the amount of matter?
Charlie:	Whenever something changes (either volume or mass) then the amount of matter changes.
Teacher:	How do your observations confirm this? [End of 7-minute chat]

Prior to engaging in ELK, both instructors demonstrated the Changing Paper and Freezing Water investigations. PSTs were able to observe shape and volume changes at home in these online methods courses. However, without digital scales for every PST, the instructors demonstrated the unchanging weight of the paper and water/ice bottle. The instructors also introduced PSTs to claims, evidence, and reasoning in the context of science education (McNeill et al., 2006), broadly, and with respect to these investigations, in particular. Also prior to ELK, the instructors introduced strategies to elicit student thinking including asking students to share claims, evidence, and reasoning; asking more open-ended than closed-ended questions; and avoiding telling or funneling (Wood, 1998) as they aimed to elicit thinking.

After ELK, both instructors used a template on which the PSTs could paste their two ELK transcripts in which they were in the role of teacher. PSTs were asked to code for prompts that they used to encourage students share their constructed arguments (i.e., to prompt argument construction) within the ELK chat transcripts. They were *not* asked to create sub-codes to identify different types of argument construction prompts. They did not code for argument critique since each ELK chat was about eliciting one student’s constructed argument. PSTs were asked to code for other features of their transcripts, for example, coding open-ended questions; analysis of PSTs’ coding of features are not included in the present study.

Practice Space 2: Avatar-Based Simulation (ABS)

The ABS practice space allows PSTs to facilitate a 20-minute argumentation discussion with five student avatars within the upper elementary Mursion® simulated classroom environment (Mikeska et al., 2019) (Figure 2). The student avatars (hereafter, “students”) are played by a simulation specialist who responds as all five students during the discussion. This simulation specialist receives extensive training from both Mursion and the larger study team about how to embody and voice the students, the students' initial ideas, and how those ideas might change with prompting by the teacher or other students.

Figure 2

Student Avatars in the Upper Elementary Mursion® Simulated Classroom

Prior to engaging in the ABS practice space, the PSTs received a written scenario to prepare to facilitate the "Making Lemonade" argumentation discussion (Mikeska et al., 2021). The scenario describes that prior to the discussion, the class completed the Freezing Water and Changing Paper investigations, and that the avatars were grouped to plan and carry out an investigation of whether matter is conserved when mixing sugar, water, and lemon juice to make lemonade. In the scenario, Will and Emily did not think that matter was conserved since volume changed. Jayla thought that matter was conserved since she observed that weight did not change.

Carlos and Mina used evidence from prior investigations to suggest that matter was conserved. Using the information above, the PSTs needed to facilitate a discussion that encouraged students to engage in argument construction and critique and come to consensus about whether matter was conserved when making lemonade.

To prepare for the ABS discussion, both teacher educators guided their PSTs through the content of the Making Lemonade investigation—demonstrating and discussing key aspects of the investigation and the big idea that while volume changed, the weight stayed the same. Additionally, both teacher educators helped the PSTs prepare for the discussion. This included (1) allowing PSTs to work in breakout groups to discuss the structure of the discussion and discussion prompts they might use to engage students in sharing their initial constructed arguments and engaging in argument critique, and (2) asking PSTs to write their discussion plan and prompts into an organizational document called a "discussion frame." Both instructors shared an argumentation video of a PST from another course facilitating the Making Lemonade discussion in the simulated classroom. This video was used as a means to not only show PSTs what the discussion would look like with student avatars but also to have PSTs practice noticing ways in which the PST facilitated the discussions. After each PST facilitated the ABS discussion in the simulated classroom over the course of one week, PSTs reflected on their discussions in breakout groups and as a whole class.

Each PST completed an assignment to analyze their ABS discussion transcripts or videos, as described below. A key aspect of this analysis was coding their transcripts for instances in which they prompted students to engage in argument construction or critique. PSTs coded for other discussion features, as well, but those are not included in the present study. PSTs were *not* asked to create and apply sub-codes for argument construction or critique.

Data Sources and Analysis

Data Sources

Both teacher educators in this study enabled their PSTs to engage in a total of four ELK chats: two playing the teacher and two playing a student (either Charlie or Dana). PSTs were able to save and analyze the transcripts from the two chats in which they played the role of the teacher. In ABS, each of the 10 participants facilitated one video-recorded discussion in the simulated classroom. In one methods class (n = 6) at Institution B, PSTs coded their ABS videos using GoReact. These codes were added to discussion transcripts to prepare for this study's analysis. In the other methods class (n = 4) at Institution A, PSTs were provided with auto-generated transcripts of their discussions and then asked to correct and code those transcripts. In both courses, PSTs were asked to code examples of when they used prompts to engage students in argument construction (ELK and ABS) or critique (ABS only).

Argument Construction Analysis

For both ELK and ABS, we generated "researcher coded" transcripts reflecting our coding of the transcripts for prompts that encouraged argument construction (Saldaña & Omasta, 2018). The first two authors did so individually, compared their coding, and came to a consensus. Prior to coming to a consensus, the coder agreement for argument construction was 87% for ELK and 80% for ABS.[1]

Our coding of the transcripts also went a step beyond the coding that we asked the PSTs to do in that we identified and applied of sub-codes that aimed to describe different types of argument construction prompts; PSTs were not asked to do this level of coding. We did so to

[1] The two first authors coded one PST's ELK transcripts together and then independently coded the other nine PSTs transcripts (18 transcripts total) independently. We calculated the coder agreement based on our initial agreement about whether teacher turns in these transcripts were prompts to elicit argumentation construction or not. We independently coded the 10 ABS transcripts to arrive at our initial coder agreement.

characterize the range of types of prompts that the PSTs used and see if there were any types of argument construction prompts that were coded more or less often by PSTs as being examples of argument construction. The first two authors independently developed sub-code lists, applied those sub-codes, and came to a consensus on the code list and assignment of codes to transcript excerpts. Note that a particular teacher turn within the transcript that the researcher or PST coded as argument construction may be assigned more than one sub-code. See Table 1 for argument construction sub-codes, descriptions, and examples.

Table 1

Argument Construction Sub-codes

Name	Description	Example from PST Transcripts
Claim	Eliciting a claim	"Do you think matter was conserved or changed in both the paper and water [investigations]?" (PST 200)
Evidence	Asking for evidence	"What evidence do you have?" (PST 104)
Justification	Asking for justification or reasoning to support a claim	[After Jayla shared that matter was conserved.] "Why do you think that?" (PST 209)
General*	Asking general questions about a constructed argument	"Can you please tell me what you found in your investigation?" (PST 205)
Revise*	Asking if students want to revise their ideas	"Is there anything that maybe we have realized, or maybe we might have a different opinion on after we've had this discussion?" (PST 203)
Consensus*	Asking students to construct a consensus argument	"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." (PST 114)

* Sub-coded in ABS only.

While we identified the sub-codes *claim*, *evidence*, and *justification* in both ELK and ABS transcripts, we identified additional sub-codes in the ABS transcripts. (Note: For clarity, hereafter we italicize sub-code names.) The ELK chats served as important precursors to the

ABS discussions and helped PSTs to hone their skills in eliciting constructed arguments. The longer-duration ABS discussions aimed to have students not only share their initial ideas but also potentially revise them and come to a consensus, creating opportunities for PSTs to try out a wider range of argument construction prompts. These prompts included encouraging students to *revise* their ideas and come to a *consensus* as a group; they also included more *general* prompts for students to share their arguments.

We compared our argument construction codes with the PSTs' coding for argument construction. When PSTs coded an excerpt as argument construction that we also coded as argument construction, this represented an accurate instance of PST noticing. For example, in ELK, PST 203 noticed "Did the amount of matter change?" as a prompt to elicit argument construction, as did we. When PSTs did not code such an excerpt, this was an instance of not noticing. PST 203, for example, did not notice the following question in ELK as eliciting a students' constructed argument: "Do you think that we gained or lost matter when we crumpled [the paper] in a ball?" We calculated the percentage of researcher-coded instances noticed by all PSTs—as well as on average per PST—for the broad argument construction code within (1) two ELK transcripts for which each PST was a teacher and (2) each ABS transcript.

We also calculated the number and percentages of sub-codes identified by researchers that all PSTs identified in their coding as prompts to encourage argument construction. We did so to explore whether types of questions and prompts were more or less frequently noticed by PSTs as being examples of argument construction.

Argument Critique Analysis

Argument critique was not an explicit emphasis of ELK, which focused on eliciting ideas; however, argument critique was a key part of ABS. Analysis proceeded similarly to what is described above for argument construction regarding what PSTs noticed and did not notice in comparison to the researcher-coded prompts to encourage argument critique. Prior to coming to a consensus, coder agreement for argument critique between the first two authors was 92%. The first two authors also developed sub-codes for different types of argument critique prompts to explore whether particular types of argument critique prompts were noticed more often than others. See Table 2 for argument critique sub-codes, descriptions, and examples.

Table 2

Argument Critique Sub-codes

Name	Description	Example from PST Transcripts
Agree/ Disagree	Asking if groups agreed/ disagreed with one another	“Does anybody want to say something to Carlos about his idea? Do you agree? Do you disagree?” (PST 112)
Compare	Asking students to compare their ideas with others	“And … was [your reasoning] ... similar to Carlos or is it different?” (PST 207)
Convince	Asking groups/students to try to convince or persuade another group	“Does anyone want to use their prior knowledge from other investigations … to maybe help Will and Emily take a different point of view on this?” (PST 203)

Findings

Noticing Argument Construction

Across all 10 PSTs, there were 63 researcher-coded instances of argument construction in the ELK transcripts and 95 in the ABS transcripts. Overall, the 10 PSTs noticed 57% (36 of 63) researcher-coded instances of argument construction in the ELK transcripts and 61% (58 of 95 total) in ABS transcripts.

Another way to analyze these data is to examine how many argumentation construction prompts are coded or noticed by a single PST on average. Table 3 presents our findings per PST; as such it includes means and standard deviations. One finding in the table is that both ELK and

ABS provided PSTs with opportunities to practice using argument construction prompts—on average 6.0 per PST for ELK and 9.5 per PST for ABS. Of these, PSTs noticed on average 58% and 57% of these prompts in ELK and ABS, respectively, per PST. These percentages are similar to but not exactly the same as the percentage of argument construction prompts noticed by all 10 PSTs (57% and 61%) described in the preceding paragraph.

Table 3

Researcher Coding and PST Noticing of Argument Construction Instances per PST

	ELK M (SD)	ABS M (SD)
Number of teacher turns per PST	15.8 (4.6)	42.9 (12.0)
Number of researcher-coded argument construction instances per PST	6.0 (2.6)	9.5 (4.7)
Number of PST-coded argument construction instances per PST	1.8 (1.2)	5.8 (5.0)
Percentage of PST-noticed argument construction instances per PST	58% (23%)	57% (35%)

Table 4 presents the sub-coding that we as researchers did to investigate if PSTs were more or less likely to notice or code particular kinds of instances as prompts to encourage argument construction. Note that the numbers in this table are for the total number of instances across all 10 PSTs for ELK, for ABS, and then for ELK and ABS together. We share the ELK and ABS findings separately to demonstrate the similarity in findings across these two online practice spaces with respect to the claim, evidence, and justification sub-codes. Note that PSTs noticed 70 or 71% of researcher-coded instances for prompts sub-coded as *claim* or *evidence*. PSTs noticed 38% of *justification* sub-codes in ELK and 45% of those codes in ABS. When combining ELK and ABS transcripts, PSTs noticed 71% of prompts to encourage argument construction that we sub-coded as *claims* and *evidence*, and 42% of prompts we sub-coded as *justification*. This finding suggests a lower likelihood of PSTs noticing justification prompts—

despite there being about as many opportunities to notice argument construction prompts that researchers sub-coded as *justification* (n=57) as there were to notice those sub-coded as *claim* (*n*=55).

Table 4

PST Noticing of Argument Construction Sub-codes across All PSTs

	ELK		**ABS**		**ELK and ABS**	
Argument Construction Sub-code	Number of researcher-coded instances across all chats	Number (percentage) noticed across all PSTs	Number of researcher-coded instances across all discussions	Number (percentage) noticed across all PSTs	Number of researcher-coded instances across all chats and discussions	Number (percentage) noticed across all PSTs
Claim	27	19 (70%)	28	20 (71%)	55	39 (71%)
Evidence	7	5 (71%)	14	10 (71%)	21	15 (71%)
Justification	26	10 (38%)	31	14 (45%)	57	24 (42%)
Consensus	-		22	15 (68%)	22	15 (68%)
General	-		10	9 (90%)	10	9 (90%)
Revise	-		10	6 (60%)	10	6 (60%)

One example of the challenge of noticing justification prompts is from PST 104. This PST noticed all three researcher-coded prompts that they used to encourage students to share claims and the one researcher-coded prompt they used to encourage them to share evidence. However, of the five prompts that researchers identified in which PST 104 was encouraging students to share their justification or reasoning, PST 104 only noticed one. They noticed the question: “So Mina can you share with the class, why you think that?” This question was asked after Mina claimed that “the amount of matter didn’t change.” They did not notice prompts such as “And can you share with the class why you think that?” [Directed to Jayla after Jayla claimed that the amount of matter didn't change] or "Will and Emily, can you explain to Carlos and Mina how you supported your claim that matter was not conserved?" Note that PST 104 did not code these or the other researcher-coded justification examples of argument construction.

Other sub-codes that were in ABS only were *general*, *consensus*, and *revise*. PSTs coded 90%, 68%, and 60% of these prompts, respectively, as instances of encouraging argument construction. For example, PST 200 noticed all three of their argument construction prompts that the researchers sub-coded as *general*, including "Okay, Will and Emily, can you tell me what you guys found from your investigation?" PST 114 coded two of five prompts as argument construction that researchers sub-coded as *consensus*. One that PST 114 did not code was "What is our final claim about whether matter was or was not conserved?" However, one prompt that PST 114 did code as argument construction included the following prompt to construct a consensus argument:

> 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. (PST 114)

With regard to the revise sub-code, PST 207 noticed the following argument construction prompt that researchers sub-coded as *revise*:

> Thinking about what we have talked about, from what your guys' statements have said, is there anything that maybe we have realized, or maybe we might have a different opinion on after we've had this discussion? If not, that's fine. I was just wondering if anyone else had an idea. (PST 207)

However, PST 203 did not notice a similar prompt: "Does that change your point of view at all Will or Emily? Either of you can respond."

Noticing Argument Critique

Overall, the 10 PSTs noticed 65% (22 of 34) researcher-coded instances of argument critique in ABS. In other words, there were a total of 34 prompts that researchers coded as argument critique, and 22 of those were coded by the 10 PSTs. See Table 5 for our analysis—per PST—of teacher turns, argument critique instances coded by researchers, argument critique instances coded by PST, and the percentage of argument critique instances PSTs noticed.

Table 5

Researcher Coding and PST Noticing of Argument Critique Instances per PST

	M (SD)
Number of teacher turns per PST	42.9 (12.0)
Number of researcher-coded argument critique instances per PST	3.4 (2.5)
Number of PST-coded argument critique instances per PST	2.2 (2.1)
Percentage of PST-noticed argument critique instances per PST	67% (35%)

PSTs seemed most adept at noticing prompts—i.e., identifying prompts as instances of encouraging argument critique—to ask students if they agreed or disagreed with one another (Table 6). For example, PST 112 identified this set of questions as argument critique: “Does anybody want to say something to Carlos about his idea? Do you agree? Do you disagree?” The two areas of argument critique that are less likely to be identified as prompts to encourage argument critique included those researchers sub-coded as *convincing* and *comparing*. For example, PST 203 did not notice the three instances when she encouraged students to *convince* one another (e.g., “Does anyone want to use their prior knowledge from other investigations … to maybe help Will and Emily take a different point of view on this?). PST 207 noticed her request for students to *compare* in one instance ("And … was [your reasoning] ... similar to Carlos or is it different?") but not in another ("So, you did something … similar to Mina and Carlos, is that correct?") indicating inconsistencies in noticing opportunities for comparing as part of argument critique.

Table 6

PST Noticing of Argument Critique Sub-codes (ABS only) across All PSTs

Argument Critique Sub-code	Number of researcher-coded instances across all discussions	Number (percentage) noticed across all PSTs
Agree/Disagree	19	17 (89%)
Convince	11	5 (45%)
Compare	6	1 (12%)

Discussion

This study is unique in that it explores PSTs' abilities to notice argumentation construction and critique across two online approximations of practice that build in complexity around a similar science topic. The PSTs' first opportunity to notice in this way was with respect to their ELK chats. These short, 7-minute, chats produced simple transcripts between themselves as a teacher and one student (Charlie or Dana) as a learner. The ELK practice space enabled PSTs to practice eliciting constructed arguments around the Changing Paper and Freezing Water investigations in a one-on-one chat with a student. The ABS practice space expanded the PSTs' task to include engaging five student avatars in an argumentation discussion in which students are encouraged to engage in both argument construction and critique. Our sub-code analysis also revealed that the more complex ABS task provided opportunities for a broader range of prompts to encourage argument construction. Sub-codes to classify teacher prompts to encourage argument construction in ABS included not only *claims*, *evidence*, and *justification* (prompts also used in ELK), but also *general* requests to share arguments, and prompts for students to come to a *consensus*, and *revise* their arguments.

Furthermore, the PSTs noticed slightly more than half of their argument construction prompts in ELK. Even though the complexity of the task increased, they noticed about the same percentage of argument construction prompts in ABS. Our sub-code analysis suggested that the type of argument construction prompt that was more challenging for PSTs to notice for both ELK and ABS was when PSTs asked students to provide justification or reasoning. This is consistent with prior work by Lottero-Perdue et al. (2022) where PSTs often did not code instances of eliciting reasoning in discussion transcripts. It is also consistent with other studies that suggest that PSTs' noticing with respect to science and engineering practices may not be consistent across all aspects of a practice (Dalvi & Wendell, 2017; Luna et al., 2018; Talanquer et al., 2013).

There were overall fewer PST prompts to encourage argument critique (on average about 3 of 43 prompts per discussion) as compared to argument construction (about 10 of 43) in each ABS discussion. Mikeska and Howell (2020) and Lottero-Perdue et al. (2022) also found in their studies the PSTs' sense-making discussions emphasized argumentation construction rather than argumentation critique. However, the PSTs did notice slightly more prompts related to argumentation critique than argumentation construction, as about two thirds of PSTs noticed prompts that encourage argument critique. Most of the argumentation critique prompts the PSTs implemented and noticed asked whether/why students agreed or disagreed with one another (they noticed 90% of these instances). This argumentation critique talk move was also most prevalent in Mikeska and Howell's (2020) and Lottero-Perdue et al.'s (2022) findings. Furthermore, while noticing agree/disagree prompts was relatively easy for PSTs, they were less likely to notice other moves—which were also used less often—to encourage argument critique, including asking students to convince one another and compare student ideas.

Based on these findings, it is evident that the PSTs relied heavily on the one talk move strategy provided by Michael and O'Connor (2012) to encourage argumentation critique - "Do you agree/disagree?" (p. 11). As a result, the talk moves the PSTs implemented to facilitate argumentation critique were often formulaic and did not always result in students engaging in a deeper level of sensemaking, which Reigh and Osborne (2021) refer to as "pseudoargumentation" (p. 2). This suggests there is a need to expand upon current talk move strategies and develop a tool that has specific moves related to facilitating scientific argumentation construction and critique discussions. Furthermore, teacher educators should be more intentional about helping PSTs notice questions or prompts that encourage critique that move beyond just agree/disagree and ask students to compare ideas or convince their peers.

Further, we agree with others who assert that providing more opportunities for PSTs to practice and notice will help them better respond in the moment while teaching (Levin et al., 2009; van Es & Sherin, 2002; Sherin & van Es, 2009; Windschitl et al., 2011). Specifically, we argue that providing more opportunities for PSTs to practice facilitating argumentation discussions, coupled with more opportunities to analyze and notice the teacher prompts that they and others use within those discussions, will serve to broaden PSTs' repertoires of teaching moves to facilitate argumentation discussions. For example, teacher educators who provide PSTs with examples of ways to encourage argument critique beyond prompts to inquire about agreement/disagreement will help PSTs see the utility in asking students to compare ideas with one another and try to convince or persuade one another. Perhaps PSTs may not notice these moves in their own (or others') transcripts, but teacher educators can help them learn to notice these moves. This strengthens the first two aspects of van Es and Sherin's (2002) noticing framework—noticing salient features that are connected to teaching principles—so that the third aspect, informing future instructional decisions, can be employed.

Our work contributes to the science education community's conversation about how to help PSTs learn to engage in the ambitious science teaching practice of facilitating argumentation discussions. Specifically, we have been able to discern in our small sample those prompts that PSTs used to encourage argument construction and critique that they are more or less likely to notice in their analysis of these discussions (Note, however, that this small sample size limits our ability to generalize beyond the sample.). By identifying what novice teachers do and do not notice, teacher educators can focus on more challenging aspects of argumentation. To support PSTs with noticing more nuanced prompts related to argumentation construction and critique, we recommend deepening PSTs' knowledge of scientific argumentation by having them analyze and code transcripts using the sub-codes of argumentation construction and critique outlined in this study. By narrowing their noticing even further, it is possible that PSTs' responses to student thinking during scientific argumentation discussion would become less repetitive and more authentic.

Future Work

We look forward to including additional participants—and more diverse participants—in this study from our ongoing work with teacher educators and PSTs in our larger aforementioned NSF research project. We are also curious about how argumentation prompts and associated noticing may be different in a third practice space in this study, the Virtual Teaching Simulator (VTS). This third practice space adds more complexity beyond the ABS practice space. In this space, the PST embodies a teacher avatar who can interact independently with two table groups of students (each containing two pairs of students who worked together) and then hold a class discussion across the table groups. Further, we will also investigate how teacher educators' instructional moves can help PSTs to engage in all three aspects of noticing (van Es and Sherin, 2002), including using what was noticed in prior practice space engagement to inform subsequent discussion strategies.

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