



# Framing Oneself and One Another as Collaborative Contributors in Small Group Argumentation in a Science Classroom

Heesoo Ha<sup>1</sup> · Heui-Baik Kim<sup>2</sup>

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## Abstract

Studies in science education have explored contextual features that facilitate students' active participation in discussion in argumentation activities. Based on this literature, we aimed to explore students' practices as they shifted their epistemic practices from unproductive to collaborative meaning-making discussion in an argumentation activity in a science classroom. We examined the discursive interactions of a small group with students who attempted to engage in interaction with one another, facilitating the negotiation of group members' positional framings as collaborative contributors during an argumentation activity. Although the students suggested ideas and engaged in interactions, the students' interactions were first dependent on a student holding higher epistemic authority (a polarized collective zone of interaction). The students' shift to collaborative contributors was shown in separate zones of interaction from a student with higher epistemic authority, led by a student who repeatedly attempted to elicit other students' reasoning. Then, at the end of the activity, this zone of collaborative contributors expanded to all of the group members, and the students jointly developed the reasoning (a collective zone of interaction). This finding indicates the importance of facilitating students in recognizing not only themselves but also one another as also potential contributors. With such acknowledgment, the students can elicit one another's ideas, facilitating them in positioning themselves as collaborative contributors in argumentation activities. We discuss the meaning of being collaborative contributors and the significance of students' role in shifting their positional framing.

**Keywords** Collaborative contributor · Positional framing · Argumentation · Small group

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✉ Heui-Baik Kim  
hbkim56@snu.ac.kr

<sup>1</sup> Department of Science Education, Seoul National University, Seoul, Republic of Korea

<sup>2</sup> Department of Biology Education, Seoul National University, 13-311, 1, Gwanak-ro, Gwanak-gu, Seoul 08826, Republic of Korea

## Introduction

Scientific argumentation has been emphasized as a core epistemic practice for constructing communal knowledge in the scientific community (Duschl & Osborne, 2002; Kuhn, 2010; NGSS Lead States, 2013). With this notion, various studies have implemented argumentation activities in science classrooms and explored students' practices in these activities (e.g. Aydeniz, Pabuccu, Cetin, & Kaya, 2012; Hand, Norton-Meier, Gunel, & Akkus, 2016). In this study, we specifically focus on the dialogical features of argumentation activities, emphasizing argumentation as an activity in which the development of reasoning to justify claims based on evidence is described as a mode of the social work of critical evaluation and revision with people (Ford, 2012; Kolstø & Ratcliffe, 2007).

Engaging in scientific argumentation implies that participants collaborate as contributors to develop valid arguments that can make sense of given phenomena (Sampson & Clark, 2009). However, in traditional science classrooms, students are described as having become accustomed to depending on an epistemic authority, such as a teacher or textbook, to acquire knowledge of scientific concepts (Cornelius & Herrenkohl, 2004). When students perceive argumentation activities from the same perspective that they have when experiencing didactic instruction, the subsequent implementation of argumentation activity does not result in their assuming the roles of producing and assessing arguments. This situation has been one of the reasons for focusing on exploring students' epistemic understanding of argumentation activities, of how knowledge would be socially constructed in an argumentation activity, and of what they are expected to do in the specific context of the activity (Hutchison & Hammer, 2010; Rosenberg, Hammer, & Phelan, 2006; Sandoval, 2005).

Students' epistemic understanding, namely, "the ideas about knowledge and knowing" (Ryu & Sandoval, 2012, p. 494), of argumentation activities has been highlighted as being reflected in their practices (Berland & Hammer, 2012; Ryu & Sandoval, 2012). Specifically, Ryu and Sandoval (2012) noted that students' understanding of an argument constructed during a discussion that aims at persuasion and consensus is an integral aspect of facilitating improvements in students' argumentation practices. Berland and Hammer (2012) inferred differences in students' epistemic understanding of argumentation activities based on their discursive practices and found that these understandings shifted dynamically according to the context of discussion as interpreted by the students. These studies underscored the importance of students' epistemic understanding of argumentation being reflected in their practices.

Furthermore, several studies about students' epistemic understanding have explored contextual cues that facilitate shifts in students' epistemic understanding of sense-making discussions in science classrooms (e.g. Hutchison & Hammer, 2010; Rosenberg et al., 2006; Shim & Kim, 2018). In Rosenberg et al.'s (2006) study, the teacher encouraged students to start with their own ideas to construct an explanation, which worked as a contextual cue that helped the students negotiate their perceptions of the activity. The contextual cues

described in these studies validated the students' ideas in the sense that they contributed to the process of developing reasonable arguments. Thus, the cues facilitated the students' perception of the activities as activities in which the value of their practices was acknowledged, thereby motivating them to actively engage in discussion. These contextual cues delineated in the literature, with a description of students' active participation in discussion afterward, have been described as one of the key aspects of facilitating shifts in students' framing of argumentation.

While exploring students' epistemic practices in the context of this type of contextual cue, we attended to two aspects of change in students' practices regarding their epistemic roles. First, how do students not only shift but also share their role as contributors? Shim and Kim (2018) described how students' positioning dynamically shifts in their discussion. We believe that one of the reasons for this situation could be that, although the cues could lead students to shift their epistemic understanding of argumentation activities, these cues are unlikely to be interpreted as such by all of the students simultaneously since there are various possible interpretations of the same situation (Goffman, 1981). This notion indicates possible misalignment in students' framing and that students would need to negotiate their differing framings with one another during interactions in the context with these cues. Second, how do students enable one another to engage in the development of argument? Engaging in collaborative knowledge-developing discussion encompasses the issue not only of participating as active participants but also of acknowledging one another as collaborating participants. Specifically, in their interaction, it would be necessary for students to propose diverse ideas, to listen to other students' ideas and consider these ideas together in their construction of arguments. In considering these aspects, we suggest that the contextual cues delineated in the literature are what trigger students' motivation to actively engage in a discussion in which they transfer their framing of the epistemic roles of themselves and one another to reach an alignment in their emergent framings as collaborative contributors. By focusing on these points, we explored students' practices as they shift their epistemic practices from unproductive to collaborative meaning-making discussion in an argumentation activity in a science classroom. We specifically explored the following research questions: (a) How do students shift their framing of one another's positions as collaborative contributors in an argumentation activity in a science classroom? (b) How are the shift and alignment of their framing facilitated in a group?

To capture students' understandings of their roles, which dynamically shift in their interactions, we focused on the case of a group in which students' understandings could be clearly revealed in their discourses during argumentation. We used the theoretical perspective of *framing* (Goffman, 1981; Tannen, 1993) to analyze such understandings. This perspective has been adopted in the literature of science education to discuss the context-sensitive dynamics of students' epistemic practices and epistemic understanding (e.g. Berland & Hammer, 2012; Shim & Kim, 2018). Based on these studies, we attempt to further our understanding of how students reflect the role of collaborative contributors in their interactions. More specifically, to capture students' epistemic understandings and practices in relation to the social context in which they are situated, we specifically focus on the positional aspect of their framing—*positional framing*—by emphasizing its relative features and transferability during interaction, as described in the following section.

## Theoretical Background

### Framing as a Perspective to Explore Classroom Dynamics

To explore the context-dependent dynamics of student epistemic practices and epistemic understanding, the theoretical perspective of *framing* has been adapted in the previous literature (Hammer, Elby, Scherr, & Redish, 2005; Hutchison & Hammer, 2010; Redish, 2004). By saying epistemic understanding, we follow Sandoval's (2005) notion of practical epistemology, which is described as "epistemological ideas that students apply to their own scientific knowledge building through inquiry" (p. 635), and the description of epistemic understanding of argument by Chen, Benus, and Hernandez (2019) as "knowing *what* and *how* to argue to produce desired knowing" (p. 1240). Practical epistemology contrasts with formal epistemologies, which are students' expressed beliefs about knowing and knowledge (e.g. Kuhn, Cheney, & Weinstock, 2000), in that practical epistemology indicates that students' ideas about knowledge and knowing can be explored in the context in which students are situated.

Framing is defined as participants' expectations of an activity in which they are situated (Goffman, 1981; Tannen, 1993), and it is typically explained as an answer to the question "What is it that's going on here?" (Goffman, 1981). This perspective focuses on the notion that participants frame a situation based on the specific aspects to which they attend, while their attention is constructed based on their similar past experiences. When a participant attends to different aspects of a particular situation, the participant's framing of the situation shifts, which is reflected in his or her practices and revealed to other participants through interactions.

The literature around framing in science education has focused on delineating shifts in student framings with respect to how students interpret the contexts in which they are placed (Berland & Hammer, 2012; Hutchison & Hammer, 2010; van de Sande & Greeno, 2012). For example, Hutchison and Hammer (2010) demonstrated that a teacher's response to a student's words could indicate a framing that focused on the idea about the mechanism, rather than the correctness of the words; this frame was transferred to the students and shifted their epistemological framing of the activity from a "classroom game" to "making sense of phenomena." This is consistent with the studies that inferred the students' epistemic understanding from their classroom practices, following Sandoval's (2005) perspective of practical epistemologies (Berland & Hammer, 2012; Ryu & Sandoval, 2012).

Based on previous studies, we aim to emphasize the following two main aspects of framing in this study: transferability and context-sensitivity. Tannen (1993) explained that a specific framing can be captured based on a participant's discursive practices (e.g. utterance, intonation, tone of voice, accent). In interactions, a participant's practices work as cues that transfer latent messages about their framing of a situation. Framing is not fixed; it can be dynamically shifted by contextual cues that participants notice in interactions with one another (Tannen, 1993). Participants can interpret one another's framing, compare their framings, and notice discordance or alignment between them (Tannen, 1993). This process can lead to context-sensitive shifts and negotiation of their framings, encouraging them to share a mutual understanding of the main goal of the activity and to collaborate to achieve this shared goal (van de Sande & Greeno, 2012).

## Perspective of Positional Framing

In the literature that has examined students' epistemic understanding of discussion in science classrooms, the issue of participant roles in discussion has been addressed as showing how students redefine their roles outside an existing frame where they formerly received knowledge transferred by an authoritative source (e.g. Hutchison & Hammer, 2010; Rosenberg et al., 2006). The positional aspect of framing refers specifically to this aspect and captures how individuals entitle or expect themselves and one another to participate in their interactions (Greeno, 2009). How participants frame their positions forms the basis of their perspective for interpreting their current situation or inferring others' interpretations of the situation, which is relevant to their understanding of the epistemic aspect of the activity (Greeno, 2009; Shim & Kim, 2018). The positions that individuals frame are explained from a relative aspect in the sense that they understand their roles in relation to one another's practices (Harré & van Langenhove, 1999; van de Sande & Greeno, 2012). We interpret this relative aspect as derived from the concept of *position* developed by Harré and van Langenhove (1999), in which *position* refers to the dynamic feature of a role, which shifts with respect to other participants in a conversation.

To explore how students negotiate their positions in response to one another's practices in their interactions in an argumentation activity, we defined and used the perspective of positional framing, which indicates how students frame themselves and one another to be capable of contributing to the construction of communal knowledge arguments. By emphasizing this relative aspect of student positioning, in addition to the features of positional framing that were discussed in previous studies, we considered another aspect of student interaction—the boundary of their interaction—as described below.

## Consideration of the Boundary of Interaction in Students' Positional Framing

Saying that someone has been framed in a particular *relative* role implies that a process of comparison among participants' different roles has occurred consciously or unconsciously (Levine, Resnick, & Higgins, 1993). Comparisons can be made of the position of participants who engage in interactions, not just a group of people who are seated together around a table. That is, positions are compared among participants who engage in interactions, and the physical proximity of the students alone cannot indicate who they actually perceive as the participants in their discussion. To address this notion, we drew on a concept called *zones of interaction*, which Shepardson and Britsch defined (2006) as “a distinct area distinguished by a spatial and temporal boundary that separates it from the surrounding peer interaction” (p. 450). They developed this concept based on Vygotsky's zone of proximal development (1978, 1986), which explores how a teacher interacts with certain students and renders this area distinct from that around other students. Shepardson and Britsch identified the following three zones of interaction based on who is taking turns in the communication and with whom the communication is occurring: an individual zone of interaction, multiple zones of interaction, and a collective zone of interaction. An individual zone of interaction refers to the interaction in which “a teacher's talk is directed only to one student at a time” (p. 451), and multiple zones of interaction refer to “two separate zones of interaction resulted” (p. 455). A collective zone of interaction refers interactions in which “the majority of utterances by one participant were addressed to the entire group” (p. 457).

In expanding from teacher-student interactions, we modified the definition of the zones of interaction as boundaries around students who are interacting with one another so that we can capture the area in which actual interactions occur in a certain group. In addition to adopting this concept, as mentioned above, we intended to distinguish different patterns of interaction and the negotiation of positional framing among the students whom we explored in this study.

We construed positional framing as students' expectations of themselves and one another within the zones of interaction in which they developed communal arguments. Then, we explored students' perceptions of who possessed knowledge and who could contribute to the construction of arguments, which could alter when their zone of interaction changed. We also observed the different patterns of interaction that the students showed as a group. We expected that a consideration of students' positional framing in their zones of interaction would help us capture students' positional framing by addressing its relative features.

## Methods

To understand how students negotiate the framing of their own and one another's positions as collaborative contributors in argumentation, we purposefully selected a group of students who could clearly demonstrate this feature using a qualitative case study approach (Merriam, 2009). We examined students' personal framing of their positions in argumentation and their transfer and alignment of framings as contributors to the co-construction of communal knowledge claims. As for the communal knowledge arguments, we interpreted them as the reasoning and claim presented, rebutted, and revised in the students' discussion. We approached students' contributions to the development of communal arguments as activating their conceptual resources and sharing them to develop reasoning that could justify a claim.

## Study Context

This study is based on data collected in a larger project on constructing a classroom environment in which students can engage in scientific argumentation. The school is located in a socioeconomically middle class area in Seoul, South Korea. We worked with one science teacher, Ms. K, and 37 seventh-grade students whose grades were at the average level in South Korea. The students' science classes were held in a laboratory with tables of four to five students; thus, they could engage in small group activities.

Ten argumentation activities about concepts related to plants and photosynthesis were implemented in the participating classroom (Appendix 1). The activities were designed to facilitate students' active participation in dialogical discussion and to support a shift in their framings. In the first lesson, before beginning the argumentation activities, the students were introduced to argumentation and the components of an argument. Then, they were asked to establish rules for the small group activities. In the following lessons, the worksheet on which the students wrote the rules that they established were placed on the students' table and were occasionally referred to by the teacher in class or by the researchers in the

interviews to allow the students to reflect on their practices based on the rules that they established. This supported the students to follow these rules in their discussion and to develop their own norms for participation in argumentation activities. The first lesson was followed by argumentation activities about different concepts. To facilitate a discussion focused on the development of reasoning and critical evaluation, the activities were designed with explicit questions that asked the students to construct arguments with valid justifications, evaluate them in discussion, and reach a consensus in each group. Information about the phenomena was provided in the students' worksheet so that they could observe and use it as evidence to support alternative claims. This aspect allowed the students to support different claims and elaborate on their reasoning in a discussion, which helped the students to engage in a social meaning-making process.

In the “**Findings**” section, we focus on describing our analysis of the students' practices and framings in the eighth lesson. This is because the students' framings changed more dynamically in later lessons, and the students' framing and framing shifts were more clearly delineated in the eighth lesson. In the eighth lesson, which was the main context of the discourse analyzed in this study, the students were asked to discuss a specific phenomenon related to bean germination. A picture that showed two beans—one with no water (Bean A) and one germinated by submerging it in water that then dried up (Bean B)—was given to the students. Then, the students were asked to develop an argument regarding which bean would be heavier and to support their argument with valid reasoning. The students were asked to construct individual arguments first so that they could later share and consider the diverse individual ideas in a group discussion. Then, to facilitate the critical evaluation of the ideas and sophisticated reasoning in the group discussion, we asked the students to develop an agreed-on argument in each group. We provided a brief explanation on the student worksheets, which were called evidence cards, of the concepts relevant to cellular respiration and germination so that the students could consider these concepts in their reasoning and facilitate a discussion.

## **Data Collection**

Each group was recorded on audio and video; researchers' observations were also recorded in field notes. We selected the groups that showed active interactions, and we conducted semi-structured interviews with them after each lesson. The interview questions were designed with a focus on the students' reflections on their practices and their cognitive understanding of the main content of the activity, as well as their social relationships during their discussions in class (examples of interview questions in Appendix 2). To explore the students' thoughts on their own practices in argumentation activities, the recordings of the students' discourse were reviewed with a focus on whether and how they reached consensus in a group discussion. Then, more concrete research questions, not just the same questions through all lessons, were contrived and asked of the students so that we could elicit their reflections on their practices that vary in each class. These interviews were also recorded, and the discursive practices in the recordings were transcribed for a more detailed analysis.

## Data Selection

To understand how the students negotiated the positional framings of themselves and of one another as collaborative contributors in a context that facilitated their active engagement in discussion, we purposefully selected a group with four students (Hyun, Min, Yeon, and Jeong) that could clearly show this feature through their discursive practices. The focus group for this study was selected based on the following criteria. First, the students' practices should reflect a shift from a dependence on epistemic authority to an engagement in discussion to contribute to the development of arguments that resulted in consent. Using the term "epistemic authority," we followed Engle and Conant's (2002) description of authority as "[an] authority in addressing [intellectual] problems" (p. 400). Because we wanted to address student authority in the context of a knowledge-developing activity, we specifically note that we focused on the *epistemic* authority of students. This notion is also consistent with Sandoval, Enyedy, Redman, and Xiao (2019) who described epistemic authority in the classroom as "who gets to be in charge of knowledge and knowledge standards" (p. 1850).

Second, the students' zones of interaction and positional framings should be clearly revealed in their discourses and behaviors during argumentation. Regarding positional framing, to be more specific, a small group whose discourses revealed that their relative epistemic authority and their expectations of how each participant would contribute to the construction of their justification was selected. Third, we examined whether the students' discussion achieved specific dialogical features, which were captured in certain discursive practices, such as proposing diverse ideas to the entire group and exchanging critical evaluations of these ideas.

In reviewing the video of the focus group practices and the transcripts, the researchers identified the parts of the discussion that clearly showed the students' positional framings and alignment of framings as collaborative contributors. The interview transcripts were also used to understand their practices and infer their framings, especially regarding their interactions and roles. Framing negotiation during discussion was observed more frequently in later lessons; therefore, the present study focuses on the eighth lesson, which was about the cellular respiration of beans, as elaborated above.

## Data Analysis

The analyzed data consisted mostly of discursive practices explored through the videos and transcripts. To analyze the students' positional framing, we first divided the context of the students' discourses into the key conceptual ideas used to develop their reasoning in the discussion. Then, the students' zones of interaction were investigated as boundaries of comparison for their positions. By defining the zones of interaction as boundaries around students who interacted, the students' responses to one another formed the center of the analysis of the zones of interaction. To investigate who engaged in the discussions as contributors to develop the reasoning, we used the following criteria to classify different zones of interaction: (a) which students were interacting with one another, and (b) which students were providing ideas to develop the reasoning. These criteria were modified from the criteria originally suggested by Shepardson and Britsch (2006). Based on these criteria, the zones of interaction were



classified as follows to develop the reasoning around each key conceptual idea: (a) a separate zone of interaction—when only two students were talking to one another and their conversation was directed only to one another at the time; (b) a collective zone of interaction—when students' talk was directed at more than two students in the group; or (c) a polarized collective zone of interaction—when the students were interacting but only two students were mainly presenting their ideas in the discussion, with the other students acting as bystanders.

Then, the students' positional framings within these zones of interactions were inductively drawn out through iterative analyses of the data (Miles & Huberman, 1994). To analyze the students' positions, we first followed the binary division suggested by van de Sande and Greeno (2012), which describes the way in which the students contributed to the construction of communal knowledge as either sources or listeners. Beginning with this broad categorization, we intended to capture the way in which the students coordinated their roles with one another in discursive interaction.

While exploring the initial coding of the discourses, we noticed that not all ideas or responses to the suggested ideas were acknowledged as valid issues for discussion. Since being a collaborative contributor in scientific argumentation implies not only speaking about an idea by oneself but also jointly sophisticating arguments and justifying their validity (Ford, 2012; Kolstø & Ratcliffe, 2007), this aspect was interpreted as indicating recognition of the person with the idea as a contributor in the zone of interaction. We subdivided the initial coding based on whether and how the students contributed to the development of the reasoning in their zone of interaction, and we attempted to answer the following questions based on their discursive practices: (a) Did the listener expect an idea that the potential source provided to be definitive or one of the possibilities? (b) How definitive was an idea that the source proposed? (c) How did the source expect the potential listener to respond to an idea that he/she proposed? (d) How did the listener respond to the proposed idea? We inferred what the students expected from one another and compared it with other students' framings within each zone of interaction to capture the discordance or alignment among their positional framings. We referred not only to the cognitive ideas that were delineated in the discourses but also to the tone of voice, facial expressions, and in the case of questions, the type of response that was expected.

The codes for the positions that are inductively drawn out and the descriptions of each position are shown in Table 1. The students framed themselves as potential contributors who present cognitive ideas to develop reasoning and expect them to be evaluated, but their framing of one another differed depending on the epistemic authority that they expected and the zone of interaction that they were in. Comparing the polarized collective zone or collective zone of interaction, we found that the students' framing of one another's positions shifted. The students' interaction shifted to the interaction in which the source proposed an idea on which a listener elaborated and then developed it into a more valid argument. The students frequently shifted between being sources and listeners and between proposing ideas and critically evaluating their validity or adding more reasoning. We coded this position as "collaborative contributors."

Based on the results of our coding, we explored how the students participated in interactions and negotiated their positional framing, and we describe the understanding of the selected part of their discussion in the next section. We aimed to establish the

**Table 1** Categorization of student positions

Perceived epistemic authority of a participant	Positions of the participant in	
	Polarized collective zone of interaction	Separate zone or collective zone of interaction
Participant with higher epistemic authority	Authoritative source <ul style="list-style-type: none"> <li>• Provides ideas in a conclusive manner that is interpreted to indicate no need for further validation</li> <li>• Assesses the “correctness” of the presented ideas</li> </ul>	Collaborative contributors <ul style="list-style-type: none"> <li>• Propose ideas that need further validation</li> <li>• Elaborate on the proposed idea by critically evaluating its validity or adding more reasoning</li> </ul>
Other participants who previously depended on the participant with higher epistemic authority	Acceptor <ul style="list-style-type: none"> <li>• Not considered to propose ideas that need to be discussed</li> <li>• Accepts ideas proposed by the authoritative source without his/her own evaluation</li> </ul>	

validity of our coding and analyses based on triangulation across multiple methods of data collection—such as recordings and transcriptions of classroom activities, interviews, and researchers’ observations—and discussion with one another to achieve consensus regarding the interpretation of the students’ practices (Merriam, 2009). Specifically, the recordings of the classroom discussions, the interviews, and the field notes taken during the activities were compared.

## Findings

In this section, we describe the case that we have analyzed, in which the students transferred and negotiated their positional framings of themselves and one another as they reached an alignment in their framing of their positions as collaborative contributors in a context that encouraged them to digress from being passive recipients of authoritative information. We organize this section in the following three contexts with the different zones of interaction that showed up sequentially: a polarized collective zone, a separate zone, and a collective zone.

### A Polarized Collective Zone of Interaction with the Discussion Centered around Hyun

Although the students suggested their ideas and engaged in interactions, their interactions showed a dependence on Hyun, who they perceived as holding higher epistemic authority. Although it seemed that the students shared their ideas with one another, Hyun and another student were mainly involved in the discussion; thus, we coded this zone of interaction as polarized collective. In the discourse shown in Fig. 1, when Yeon suggested a justification based on whether water was poured on Bean B (line 106), Hyun rebutted the idea concisely by referring to the experimental procedure of

removing water from the bean and elaborating on the intention behind the procedure (lines 106, 109). However, the other students continued to reveal their skepticism about the complete removal of water from the bean with no modification or additional reasoning (lines 111, 114, 118). We inferred that they considered Hyun's approval of the "correctness" of their ideas to be validation and were attempting to support their idea through the authority held by someone else (Sandoval & Millwood, 2007). It seemed that the students interpreted Hyun's rebuttal, although Hyun provided the experimental procedure as evidence to justify it, as a dismissal, and showed limited reasoning. We inferred that this feature of the students' discussion showed that the students framed Hyun as an authoritative source, while framing themselves as contributors.

Hyun did not attempt to propose her ideas to the other students but engaged in the discussion by responding to the other students' ideas. In the interview, Hyun revealed her skepticism regarding the other students' ideas based on her perception of their limited capability to provide valid ideas by saying, "I couldn't accept the idea [that Min proposed] because she wasn't really aware of what she was talking about." Additionally, when one researcher asked her why she did not accept the other students' ideas, she responded, "Because her [Jeong's] idea is quite fabricated ... without any evidence provided." Hyun's practices and interviews indicated her assessing attitude toward other students' ideas and that she framed herself as an authoritative source and other students as acceptors whose ideas could not be correct and needed to be revised.

The students barely included one another, except for Hyun, as valid contributors to their discussion. This was especially noticeable in the discourse in which Jeong blocked other students from talking to Hyun and tried to share her idea exclusively with Hyun (Fig. 1, lines 87–91). Not only did Jeong focus on talking to Hyun, but Jeong also

<i>Line</i>	<i>Speaker</i>	<i>Discourse</i>
87	Jeong	I mean, how much water does it lose . . .
88	Yeon	(While looking at Hyun) Hey, then . . .
89	Jeong	(Looking at Yeon, in an irritated tone) I spoke first.
90	Yeon	I didn't hear that.
91	Jeong	Listen to what others say. Anyway, it's . . .
		. . .
106	Yeon	(Looking at Min) Oh. (Looking at Hyun) Hey, since we are pouring water on this one [Bean B], won't this one become heavier?
107	Hyun	But it dries up afterward.
108	Yeon	Dries up?
109	Hyun	Because the intention was not to pour water on it but to facilitate its germination.
110	Yeon	Oh.
111	Min	But how does it dry up without any light?
112	Yeon	(Looking at Hyun) Aren't they the same [weight]?
113	Hyun	I just said that it dries up.
114	Min	But they poured water on it.
115	Jeong	No, they didn't.
116	Hyun	I'm saying that they didn't pour any water. This one sprouted and then dried up for three days.
117	Min	Oh.
118	Yeon	But still, it might not get rid of all the water in it (laughs).
119	Hyun	That's just your opinion.
120	Min	But Bean A could be heavier.
121	Hyun	That's what I said.
122	Min	Um, I don't understand (in a frustrated tone).
123	Hyun	Well, I don't get it either. Maybe they weigh the same.

Fig. 1 Discourse between the students in the polarized collective zone of interaction

ignored Yeon's comments and tried to push her idea into the interaction with Hyun instead. Jeong's practices indicated that she did not frame Min or Yeon in a position that could contribute to developing the ideas that Jeong suggested but rather considered them to be acceptors in their zone of interaction.

At the same time, Min made several attempts to change the existing features of the interactions. She showed her intention to accept other students' ideas and discuss them, which indicated her framing of herself and the other students as collaborative contributors. In the discourse, for example, she questioned Hyun's explanation of the loss of moisture of the beans (line 111) in attempting to join the interaction between Hyun and Yeon. However, Yeon did not listen to Min's discourse and moved directly to a revision of the claim based on Hyun's rejection. Dismissing her idea immediately after Hyun's rebuttal and attempting to seek an answer, Yeon revealed her persistent dependence on Hyun. Min's question was discouraged again by Jeong (line 115), who said that water was not poured on Bean B. Although Min tried to share her positional framing of the group members as collaborative contributors, Yeon and Jeong resisted shifts in their positional framing because of their strong reliance on Hyun's epistemic authority. Min also recalled this discourse as her attempts being rejected by the other students: "When I talked about something that I did not completely understand, the other students didn't acknowledge it as a potentially valid thought."

### **Elaboration of Ideas in a Separate Zone of Interaction from Hyun**

Although the other students blocked Min's attempts to participate in their zones of interaction and to expand the reasoning in the polarized collective zone of interaction, Min was the one who later facilitated the shifts in positional framing. She facilitated a separate zone of interaction with Yeon, where she was able to share her positional framing as a collaborative contributor. This change began when Yeon brought up another line of reasoning regarding cellular respiration based on one of the evidence cards, thereby starting a new discussion:

Yeon: Plants always do respiration? What does it have to do with this phenomenon?

Hyun: Because it loses weight when nutrients get decomposed by respiration.

Yeon: Oh.

Afterward, the discussion paused. The students looked at their own worksheets, and it seemed that they were thinking individually. Then, Min resumed the discussion by asking Yeon—not Hyun—for more details about the contents of the evidence card on cellular respiration (Fig. 2, line 127). It was the first time that a zone of interaction without Hyun was formed, which emerged from Min's attempt to understand the evidence on the card. At the same time, Jeong asked Hyun about the relationship between the amount of energy used and the weight of the beans and the discussion in the group proceeded into two separate zones of interaction. Considering the students' perception of Hyun's epistemic authority and Jeong's exclusion of the other students from her interaction with Hyun, Yeon seemed to be the best prospect for Min to transfer her positional framing as a collaborative contributor. We inferred that Min's initiation of

the separate zone was possible because Yeon was the one with whom she initiated this interaction.

In the beginning of Yeon and Min's zone of interaction, Yeon persistently relied on Hyun's epistemic authority, but Min tried to elicit Yeon's explanation, which reflected her positional framing in these discourses. For example, Yeon responded to Min's question that aimed for meaning-making, but it was a mere repetition of what Hyun had told her earlier (line 129). This response indicated Yeon's lasting framing of Hyun's position as an authoritative source that had been continued from the previous polarized collective zone. However, Min was not content to accept this response; she continued to ask for detailed reasoning and an explanation for Yeon's words. She also attempted to apply Yeon's explanation to the given phenomenon (lines 130, 132, 137). Min's discourse indicated that she was framing herself as capable of developing valid reasoning about the given phenomena. Furthermore, it implied that Min had recognized Yeon as another contributor who would work as a collaborative contributor and consider the validity of the arguments together with Hyun in the polarized collective zone. Additionally, by applying the information provided by Yeon, Min showed her trust in Yeon as a valid source in this knowledge building activity. Therefore, Min constantly reflected her framing of Yeon and herself as collaborative contributors in her discourse.

Consequently, Yeon showed discursive practices that indicated a shift in positional framing, which aligned with Min. In line 150, Min asked a question based on another evidence card, which led to the development of the group's justification of the usage of energy during germination. Yeon then suggested a relationship between the usage of energy during germination and a decrease in the weight of the bean, which linked the contents of the evidence card to the relevant claim that could be explained by it (line 154). Min asked "Why?" again, which facilitated Yeon in elaborating on the reasoning for this idea to persuade Min. Then, Yeon mentioned her everyday experience and elaborated on her reasoning (line 156). During the discussion, Yeon brought up more diverse ideas by using evidence cards, and Min continued to ask Yeon to help expand their collective reasoning. This exchange led to the development of their understanding of cellular respiration and improved the sophistication of their argument as they elaborated, in their own words, on the justification that Hyun had briefly mentioned.

<i>Line</i>	<i>Speaker</i>	<i>Discourse</i>
127	Min	Hey, what is that (pointing at one evidence card) supposed to mean?
129	Yeon	It means that a bean loses weight when nutrients are decomposed.
130,	Min	Oh, really? . . . But then, is this one with nutrients decomposed?
132		
136	Yeon	What was it called, umm, the nutrients are decomposed when plants do respiration?
137	Min	So, this one has decomposed nutrients?
138	Yeon	Yeah.
139,	Min	But there's no light here. Oh, never mind. (Pause) Hey, Yeon, but why does it need
150		evidence that says a lot of energy is needed when the beans germinate?
151	Yeon	Where?
153	Min	It's not necessary. If they used the energy . . .
154	Yeon	Isn't it, like, if energy goes out when it is needed, then the weight decreases?
155	Min	Why?
156	Yeon	Because it uses the energy just like us doing exercise, using the energy, and losing weight.

**Fig. 2** Discourse between the students in the separate zone of interaction with Hyun

The separate zone of interaction between Yeon and Min was initiated by Min, who was trying to understand the key concept that Yeon had raised. Their positional framings were not aligned at first, but they reached alignment in their framing through Min's constant requests for Yeon's reasoning, which allowed them to develop an argument with elaborated reasoning around the concept of cellular respiration. This positional framing, with Yeon and Min as collaborative contributors, was not present in the previous polarized collective zone with Hyun. This interaction also contrasted with the zone of interaction between Hyun and Jeong. In this zone, Jeong asked Hyun how the weight of the bean would change when the energy was used, and their interaction ended when Hyun answered the question. The disparate features of the interactions in these two separate zones indicated that the formation of the zone of interaction in which Min's positional framing could be transferred to another participant was a key initiative in the shift of the students' positional framings to collaborative contributors.

At the end of their separate zone of interaction, Yeon and Min wanted to confirm their reasoning; therefore, they asked Hyun and Jeong for their thoughts in an attempt to expand their zone of interaction into a collective one.

Yeon: (Looking at Hyun) Hey, hey, do our weights drop when we use lots of energy?

Min: (Looking at Jeong) Does it weigh less if they use lots of energy?

Hyun: When it uses more energy, more nutrients would be. . .

Yeon: Okay, I'll go with Bean A [, which weighs more,] then.

When Hyun repeated their reasoning, Yeon became confident in their rationale and the claim based on it. This exchange contrasted with the pattern of discourse in the earlier polarized collective zone of interaction. However, the discussion did not instantly expand to the collective zone, as Hyun asked Ms. K to confirm whether the beans also respire; she relied on the teacher's authority rather than discussing the question with the other students. The students' discussion showed the formation of a separate zone of interaction several times afterwards and then expanded to the collective zone of interaction at the end of the discussion.

### **A Collective Zone of Interaction with Collaborative Contributors**

At the end of the discussion, the students formed a collective zone of interaction and revisited the reasoning based on the water content in the beans. In contrast to the previous discussion on the same topic, they started to justify their claim with their ideas about the structure of beans and their everyday experiences, despite Hyun's rebuttal (Fig. 3).

In this discourse, although the topic of the discourse was not what this study had initially intended it to be, the students revisited the idea that they had proposed earlier and collaboratively made their arguments more sophisticated. The students proposed their ideas, shared critical evaluations with one another, and complemented one another's arguments. Jeong again raised a justification of the water content, which added to her idea about the structure of the beans (line 302, 304). Since Hyun had constantly rebutted this idea, she gave a tired groan (line 303) and stepped back from the discussion.

<i>Line</i>	<i>Speaker</i>	<i>Discourse</i>
302	Jeong	Can I suggest another weird idea? If it dried up only on the exterior part because of its peel, then the inside might not be dried up.
303	Hyun	(In an annoyed voice) Gosh.
304	Jeong	If it didn't dry up inside, then, it could be heavier.
305	Yeon	(Agreeing with Jeong's idea) Yeah, that's possible.
306	Jeong	(Looking at Min) Hey, I'll add another claim to your arguments. If this one didn't dry up because of the peel ...
...		
313	Min	But, if Bean A was put in a place with no light and no water, so it didn't sprout, it means that it has been drying out since then. But if Bean B was getting water in the earlier stage and then dried up, it could be possible that there's still some water here [in Bean B].
314	Yeon	Then there could be a little bit of water here [in Bean A] as well.
315	Jeong	But isn't it dried up for three days after it sprouted by pouring water?
316	Min	Yeah, but isn't it possible that there's water inside?
317	Jeong	But they were dried up for three days. Oh, yeah, it could be possible.
318	Min	We have water inside our bodies even if we don't drink water for three days. (laughs)
319	Jeong	But Hyun just said that we should consider these almost dried up. There could be hardly any water left in there after drying out for three days.
320	Min	But it's still possible.
321	Yeon	(To Hyun) But it dries up more slowly without light.
322	Jeong	Could you stand being without any water for three days?
323	Min	Sure.
324	Jeong	People cannot live without water. Without food, it may be possible for seven days. But without water, I guess, two days?
...		
326	Hyun	But the amount of water that dried up is the same in these cases.
...		
328	Yeon	Yeah, right. The amount of water that dried up is the same in these cases.
...		
337	Jeong	(To Min) I think yours could be a valid argument as well.

**Fig. 3** Discourse among the students in the collective zone of interaction

The students discussed their own ideas despite Hyun's rebuttal, which indicated that they considered their voices and ideas to be as valid as hers and reflected their framing of the activity as "making sense of phenomena." Yeon conceded the potential of Jeong's idea (line 305), which facilitated the further expansion of the discussion with the other students. Min then elaborated on Jeong's idea and justified her thought based on the length of the period of dehydration (line 313). Since the reasoning based on the procedure had been continuously rebutted before, Yeon and Jeong rebutted Min's reasoning (lines 315, 317), which was also their previous idea. Jeong's rebuttal led Min to develop the justification with a hypothetical case of people not drinking water (line 318), but Jeong rebutted this suggestion by arguing that people would be dead by then. This discourse showed that the students critically evaluated their own ideas by listening to one another. Based on these practices, it could be inferred that they framed their positions as collaborative contributors, whose proposed ideas could be acknowledged as valid to develop their arguments.

Hyun also engaged in the interaction by rebutting the reasoning about the water content by saying that the water had dried to the same level in both beans (line 326). Her idea was not a scientifically canonical idea either, but we conjectured that she wanted to indicate that the water content of both beans was irrelevant to the change in their weight. Hyun's intention was explicitly mentioned in the interview, in which she described the justification of the water content as "fabricated." In the discussion, Yeon copied Hyun's words, which indicated the other students' acceptance of Hyun's

intention. Their discussion was closed as the students agreed on the validity of the reasoning regarding the water content of the beans despite Hyun's rebuttal.

In this discourse, they critically evaluated the idea with their own words and shared the reasons that the idea was not valid by rebutting its flaws, thereby developing the argument with an additional qualifier of the claim. Although the students again dismissed the idea of water content at the end of the discussion, they acknowledged that another student's idea "could be a valid argument as well" (line 337). Their discussion advanced their reasoning by including the concept that "Bean A would be heavier if the beans were completely dried up after they were soaked to sprout." We emphasize this feature since it shows that the students changed the epistemic understanding of their practices and explicitly acknowledged their own and one another's positions as contributors to the discussion.

## Discussion

In this section, we describe how the findings of this study further our understanding of students' positioning as collaborative contributors in dialogical argumentation activities.

### Discussion in the Polarized Collective Zone of Interaction

We noticed that although the students engaged in the discussion from the beginning, discussion in the polarized collective zone was different from the discussion as collaborative contributors. We believe that the design of the argumentation activities, along with the teacher's support for students' active participation, sufficiently supported the students to shift their role from passive recipients of information to active participants in a discussion. This interpretation is supported by the students' active presentation of their ideas in the polarized collective zone. The students proposed diverse ideas from the beginning and did not remain passive recipients of information from authoritative sources. Active sharing of their own ideas is considered to be one of the main aspects of students positioning themselves as participants in knowledge construction (Rosenberg et al., 2006). The multiple voices raised in this zone could be understood as possessing the potential to change the existing pattern of interaction, although the representative feature here was the students' dependence on Hyun.

However, this discussion lacked a critical evaluation of the proposed ideas, which could hardly be interpreted as an exchange between collaborative contributors compared to the later interactions in the collective zone. The students' attention paid to Hyun's agreement with their ideas indicated their persistent reliance on Hyun, who they perceived as holding higher epistemic authority. The students lacked acknowledgement of one another, except of Hyun, as possible contributors to the development of their ideas. This feature differs from the collective zone, in which various students take chances on proposing ideas and discussing them. Although the argumentation activity that we implemented provided the context that encouraged the students to engage in the discussion and elicited their diverse ideas, the students' positioning as collaborative contributors emerged after they negotiated their positional framings in interactions. We



believe that the discussion in the polarized zone could be interpreted as the beginning of the dynamic negotiation of their positional framings.

### **Min's Contribution to the Shift in Group Members' Framing**

Min's facilitation of a framing shift in her group suggests that students' initiative roles in transferring their shifted positional framing to other participants should be considered when facilitating collaborative discussions in argumentation activities. The literature on student framing has shown how students' framing can shift context-sensitively (e.g. Shim & Kim, 2018), and studies have explored instructional supports that can transfer a teacher's productive framing to students (e.g. Elby & Hammer, 2010). These studies have focused on the interaction between a teacher and students and have compared classrooms where a teacher solely holds epistemic authority to classrooms where students also hold epistemic authority and actively participate in knowledge construction. In this study, we have focused on the interactions among students and explored how students transfer and align their positional framings. The analysis shows the significance of Min's role in the group members' positioning as collaborative contributors despite the lasting unproductive framing.

Min's positional framing led to subsequent discordance with other students' framings, followed by negotiation and shifts in the other students' framings. Specifically, the initial shift in Min's personal positional framing seemed to be initiated by her willingness to join in the other students' interactions and establish common ground on the concept of cellular respiration through discussion with the other participants. However, Min encountered Hyun's position as an authoritative source and Jeong's exclusion of the other students from her interaction with Hyun. This situation facilitated Min in seeking another participant in the discussion. This shift subsequently led to changes in the existing pattern of interaction, which initiated a separate zone of interaction from Hyun in which Hyun was able to transfer her framing of the group and facilitate Yeon to align her positional framing with Hyun's framing. We suggest that such a change in the positional framing in this separate zone worked as a stepping stone for the students to engage in a collective zone of interaction as collaborative contributors.

The dynamic changes in the students' positional framing initiated by Min's shift in her personal framing could be interpreted as in alignment with the discussion in the literature on students' practices as agents who transform ways to participate in activities in science classrooms (Varelas, Tucker-Raymond, & Richards, 2015). In the polarized collective zone of interaction, Min's attempts to join the interaction between the other students were initially not successful, because they were constrained by the other students' persistence in their framings. Confronting this discordance between her and the other students' framings, Min attempted to form a separate zone of interaction in which her framing could be shared with another student and eventually aligned with the other students after her persistent attempts. That is, motivated to share her positional framing as a contributor, Min was able to engage in a different pattern of interaction that facilitated the sharing of her framing. In addition to Min's major role in providing the contextual cues that facilitated shifts in the students' framing (Hutchison & Hammer, 2010; Rosenberg et al., 2006), her agency in terms of the shift in her positional framing as a collaborative contributor and persistent attempts to transfer her framing seemed to be the main driving forces that facilitated the group's negotiation

of its positional framing and, eventually, a productive discussion in the collective zone. This case shows us that a student's repeated attempts to initiate negotiations of her roles in a discussion could be a significant feature of her positioning of group members as collaborative contributors in argumentation. This finding suggests that, for the construction of a learning community in which students engage in dialogical argumentation, which means students' participation in the social development of knowledge, it is necessary to attend to students' contributions to facilitating joint contribution from one another. We believe that instructional strategies that support students in framing one another as collaborative contributors and playing the role of facilitating transfer of their recognition of one another as contributors can be essential to facilitating students' construction of their own collaborative learning community in a science classroom.

### **Framing as Collaborative Contributors in Argumentation Activity**

Comparing the students' discourses in the polarized collective zone and the collective zone after the negotiation of their positional framings show that being collaborative contributors is more than just being participants in a discussion. Being collaborative contributors in an argumentation activity implies that the students share a common understanding of the epistemic goal of the argumentation activity in which they are engaged, which leaves space for other participants to become involved in validating the reasoning behind the knowledge claim. This involvement is more than being a sole active participant in a knowledge construction activity or just assuming the existence of a listener on the other side.

Specifically, clear differences in the students' attitudes toward one another as listeners in each zone were noticeable. In contrast to the polarized collective zone in which they were indifferent to one another's ideas, in the collective zone, the students paid attention to one another's words and considered suggested ideas as potential constituents of the argument that they were developing. Furthermore, this framing differed from Hyun's rejection of the other students' ideas in the polarized collective zone in that Hyun's responses seemed to indicate that she was the assessor of the validity of the other students' ideas. This difference underlines that engaging in a dialogical argumentation activity implies that the participants take up the proposed ideas, including the ideas about which they are skeptical at first, and then critically evaluate their validity. This notion indicates the importance of the collaborative contributor in an argumentation activity being not only a source who actively proposes ideas but also a listener who attends to the ideas suggested by other students and acknowledges their potential, even if they do not initially agree with other students' viewpoints.

We based our analysis on positional framing (van de Sande & Greeno, 2012) and inductively drew out more specific positions from the students' discursive practices. There could be various ways of viewing students' positional framing other than the perspectives delineated in this study. Although the case explored in this study was useful in delineating students' positional framings and the dynamic shifts in the framings, we do not intend to state that this case and the dynamics described herein are the only ways for students to become or work as collaborative contributors in argumentation activities in science classrooms. It is necessary to study additional cases and explore student interactions within groups to understand the epistemic practices in

a social context and support students in positioning themselves as contributors who collaborate together in a meaning-making process in science classrooms.

## Conclusion

This study explored how students transferred and negotiated the positional framings of themselves and one another through interactions, as they achieved the framing of their positions as collaborative contributors. In this section, we address several implications of this study.

First, based on previous studies that investigated the contexts that could facilitate students' engagement in productive practices in science classrooms (e.g. Engle & Conant, 2002; Hutchison & Hammer, 2010; Rosenberg et al., 2006), the present study focused more concretely on how students negotiate their positional framings as they acknowledge one another's active roles in a discussion in an argumentation activity. In addition to the studies exploring how teachers' acknowledgment of students' diverse ideas can encourage productive discussions, this study suggests that it is important for students, and not only teachers, to share framing of one another as contributors to form a collaborative community in the science classroom. We hope that future studies will explore the dynamic shifts in positional framings during discussions to build communal understandings in argumentation and how we can facilitate students' position as contributors to such discussions.

Second, we noticed that Min's shift in her positional framing played a significant role in initiating subsequent shifts in interactions and other students' framings and epistemic practices. We think that Min's shift was motivated, at least to some degree, by the argumentation activities that aimed to encourage the students to propose knowledge claims supported by valid reasoning. Her continuous attempts to transfer her framing to the other students facilitated a collaborative discussion in the group despite the lasting positional framing that had been shared in the polarized collective zone of interaction. This study suggests that it is important for students, and not only teachers, to frame one another as contributors, which is transferred to other group members and supports them in joining in the co-development of knowledge to form a collaborative learning community in the science classroom. We suggest that future studies that aim to promote dialogical argumentation in science classrooms attend to this contribution from students to facilitate other group members' framing shift.

Third, the findings show that being collaborative contributors is more than just engaging in discussion in that being collaborative contributors allowed other participants to suggest ideas that would be acknowledged as resources and to become involved in the modification of the proposed ideas. The alignment as collaborative contributors emerged, as the students encountered discordance multiple times and dynamically shifted their framings. The dynamic shifts in students' framings and interaction patterns could be necessary steps since the students encountered argumentation activities in which they all could raise their voices. Future studies could investigate the features of the interactions that facilitate students' alignment of their positional framing of themselves and one another as collaborative contributors at the time that they encounter discord in their framings.

Finally, this study suggests that science educators need to attend to students' framing of their relative positions, which is constantly negotiated during interactions, and how

they allow one another to engage in discussion in a context that facilitates active participation in such discussion. Although the teacher's role of providing support for students' participation in dialogical discussion was not discussed in depth, due to the focus of this study, teachers obviously play an important role in supporting students' productive participation in argumentation activities. The alignment of positional framing as collaborative contributors in the explored case emerged during the students' complex exchange of their framing as meta-messages in their interactions. To support this emergent achievement of collaborative positions in dialogical argumentation, we suggest that science educators provide a classroom environment for students to share their framings and examine their dynamic negotiation of positional framing in diverse types of interaction. It is also necessary for teachers to support students in perceiving one another as collaborative contributors by facilitating other students to engage in critical evaluation and sophistication of their reasoning. Many students only show participation in a discussion with a teacher and stop their participation without the teacher's presence, even in argumentation activities that are designed to facilitate their productive discussion. Based on the findings of this study, we believe that the instructional supports that facilitate students in framing one another as potential contributors and facilitate a transfer of such positional framing can support students to work as collaborative contributors, rather than as individual learners, and to develop collaborative discussion in dialogical argumentation in science classrooms.

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## References

- Aydeniz, M., Pabuccu, A., Cetin, P. S., & Kaya, E. (2012). Argumentation and students' conceptual understanding of properties and behaviors of gases. *International Journal of Science and Mathematics Education, 10*(6), 1303–1324.
- Berland, L. K., & Hammer, D. (2012). Framing for scientific argumentation. *Journal of Research in Science Teaching, 49*(1), 68–94.
- Chen, Y.-C., Benus, M. J., & Hernandez, J. (2019). Managing uncertainty in scientific argumentation. *Science Education, 103*(5), 1235–1276.
- Cornelius, L. L., & Herrenkohl, L. R. (2004). Power in the classroom: How the classroom environment shapes students' relationships with each other and with concepts. *Cognition and Instruction, 22*(4), 467–498.
- Duschl, R. A., & Osborne, J. (2002). Supporting and promoting argumentation discourse in science education. *Studies in Science Education, 38*(1), 39–72.
- Elby, A., & Hammer, D. (2010). Epistemological resources and framing: A cognitive framework for helping teachers interpret and respond to their students' epistemologies. In L. D. Bendixen & F. C. Feucht (Eds.), *Personal epistemology in the classroom: Theory, research, and implications for practice* (pp. 409–434). Cambridge, England: Cambridge University Press.
- Engle, R. A., & Conant, F. R. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners classroom. *Cognition and Instruction, 20*(4), 399–483.
- Ford, M. J. (2012). A dialogic account of sense-making in scientific argumentation and reasoning. *Cognition and Instruction, 30*(3), 207–245.
- Goffman, E. (1981). *Forms of talk*. Philadelphia, PA: University of Pennsylvania Press.
- Greeno, J. G. (2009). A theory bite on contextualizing, framing, and positioning: A companion to son and goldstone. *Cognition and Instruction, 27*(3), 269–275.

- Hammer, D., Elby, A., Scherr, R. E., & Redish, E. F. (2005). Resources, framing, and transfer. In J. Mestre (Ed.), *Transfer of learning: Research and perspectives* (pp. 88–119). Greenwich, England: Information Age Publishing.
- Hand, B., Norton-Meier, L. A., Gunel, M., & Akkus, R. (2016). Aligning teaching to learning: A 3-year study examining the embedding of language and argumentation into elementary science classrooms. *International Journal of Science and Mathematics Education, 14*, 847–863.
- Harré, R., & van Langenhove, L. (Eds.). (1999). *Positioning theory*. Oxford, England: Blackwell.
- Hutchison, P., & Hammer, D. (2010). Attending to student epistemological framing in a science classroom. *Science Education, 94*(3), 506–524.
- Kolstø, S. D., & Ratcliffe, M. (2007). Social aspects of argumentation. In S. Erduran & M. P. Jimenez-Aleixandre (Eds.), *Argumentation in science education: Perspectives from classroom-based research* (pp. 117–136). Dordrecht, The Netherlands: Springer.
- Kuhn, D. (2010). Teaching and learning science as argument. *Science Education, 94*(5), 810–824.
- Kuhn, D., Cheney, R., & Weinstock, M. (2000). The development of epistemological understanding. *Cognitive Development, 15*(3), 309–328.
- Levine, J. M., Resnick, L. B., & Higgins, E. T. (1993). Social foundations of cognition. *Annual Review of Psychology, 44*, 585–612.
- Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation* (2nd ed.). San Francisco, CA: Jossey-Bass.
- Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.). Thousand Oaks, CA: Sage.
- NGSS Lead States. (2013). *Next generation science standards: For states by states (appendix F)*. Washington, DC: National Academies Press.
- Redish, E. F. (2004). A theoretical framework for physics education research: Modeling student thinking. In E. Redish & M. Vicentini (Eds.), *Proceedings of the Enrico Fermi summer school, course CLVI* (pp. 1–64). Bologna, Italy: Italian Physical Society.
- Rosenberg, S., Hammer, D., & Phelan, J. (2006). Multiple epistemological coherences in an eighth-grade discussion of the rock cycle. *Journal of the Learning Sciences, 15*(2), 261–292.
- Ryu, S., & Sandoval, W. A. (2012). Improvements to elementary children's epistemic understanding from sustained argumentation. *Science Education, 96*(3), 488–526.
- Sampson, V., & Clark, D. (2009). The impact of collaboration on the outcomes of scientific argumentation. *Science Education, 93*(3), 448–484.
- Sandoval, W. A. (2005). Understanding students' practical epistemologies and their influence on learning through inquiry. *Science Education, 89*(4), 634–656.
- Sandoval, W. A., & Millwood, K. A. (2007). What can argumentation tell us about epistemology? In S. Erduran & M. P. Jiménez-Aleixandre (Eds.), *Argumentation in science education* (pp. 71–88). Dordrecht, The Netherlands: Springer.
- Sandoval, W. A., Enyedy, N., Redman, E. H., & Xiao, S. (2019). Organising a culture of argumentation in elementary science. *International Journal of Science Education, 41*(13), 1848–1869.
- Shepardson, D. P., & Britsch, S. J. (2006). Zones of interaction: Differential access to elementary science discourse. *Journal of Research in Science Teaching, 43*(5), 443–466.
- Shim, S. -Y., & Kim, H. -B. (2018). Framing negotiation: Dynamics of epistemological and positional framing in small groups during scientific modeling. *Science Education, 102*, 128–152.
- Tannen, D. (1993). *Framing in discourse*. New York, NY: Oxford University Press.
- van de Sande, C. C., & Greeno, J. G. (2012). Achieving alignment of perspectival framings in problem-solving discourse. *Journal of the Learning Sciences, 21*(1), 1–44.
- Varelas, M., Tucker-Raymond, E., & Richards, K. (2015). A structure-agency perspective on young children's engagement in school science: Carlos's performance and narrative. *Journal of Research in Science Teaching, 52*(4), 516–529.
- Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.
- Vygotsky, L. S. (1986). *Thought and language* (Rev ed.). Cambridge, MA: MIT Press.