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Argumentation as/in/for dialogical relation: A case study from elementary school science

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Abstract

Argumentation as a form of introducing children to science has received increasing attention over the past decade. Argumentation tends to be studied and theorized through the lens of individual speakers, who contribute to a conversation by means of opposing statements. M. M. Bakhtin and L. S. Vygotsky independently proposed a very different approach by suggesting that dialogical relations inherently and irreducibly embody argumentation. From this position, dialogical relations allow children to individualize argumentation. In this study, we show how the dialogical framework provides a very different, collective perspective on children's argumentation in problem solving processes in elementary science classrooms.

Keywords: Argumentation · dialogue · problem posing · solution finding · Bakhtin · Vygotsky

Rethinking argumentation in classroom contexts

Argumentation has been of increasing interest in the science education as a means of actively involving students in science and, thereby, as a means of promoting their learning (Duschl & Osborne, 2008). However, many approaches to teaching argumentation place primacy on teaching the structure of the argumentative genre prior to and at the beginning of participating in argumentation. Such an approach, however, is absolutely impossible according to pragmatist philosophers of language (e.g., Davidson, 1986; Rorty, 1989; Wittgenstein, 1953/1997), for to learn the structure of argumentation, one already needs to be competent in argumentation. The purpose of this paper is to offer a different theoretical approach based on dialogical relations (Bakhtin, 1984), as the origin of internal dialogue (inner speech) and higher psychological functions (Vološinov, 1930; Vygotskij, 2005). In this approach, argumentation first exists *as* dialogical relation, for participants who are *in* a dialogical relation with others, and who employ argumentation *for* the purpose of the dialogical relation. We provide several fragments of second/third-grade children's conversations in a science classroom to describe and as a basis for explaining how argumentation emerges and develops *as*, *in*, and *for* dialogical relations with others. This sets the stage for argumentation to show up some time later when students are tested individually.

As educators have come to recognize children's critical thinking and problem solving skills as crucial ingredients of scientific literacy, there has been a concurrent, widespread emphasis on

argumentation as a way of developing critical and creative minds. Recent studies on argumentation in science classrooms have suggested engaging students in argumentative discourse with claim making, critical evaluation of evidence, and justification as effective methods to enhance children's reasoning and scientific thinking (Bricker & Bell, 2008; Driver, Newton, & Osborne, 2000; Jimenez-Aleixandre & Erduran, 2007; Kuhn, 2010; Osborne, Erduran, & Simon, 2004; Roberts & Gott, 2010; Sadler, 2004). Numerous studies have focused on how children practice and construct the structure of argumentation, for instance, children engage in contradictory situations with two or more opposite ideas and make their own decisions concerning the possible consequences of their decisions. Occasionally, asked students to speak or write about what they "think" and would "do" in given contradictory or conflictual situations. During the task engagement, children were to articulate their (inner) thoughts to be examined on the part of researchers and educators in terms of how capable children are in terms of reasoning and constructing their argumentation. Toulmin's Argumentation Patterns (TAP) (e.g., Erduran, Simon & Osborne, 2004; Roberts & Gott, 2010; Simon, 2008) is the most widely used framework to examine children's argumentation. TAP suggests six components of argumentation; claims, ground, warrant, backing, rebuttal, and qualifier to justify a claim as a good argument (Toulmin, 1958). In the associated approach to teaching, children were encouraged to make claims, look for evidence, and evaluate their claims against evidence, and justify their conclusions; and researchers looked for the components of argumentation in children's written or verbal expressions to analyze argumentation skills. Yet, researches in argumentation also reviewed the limitations of analyzing children's argumentation with TAP framework such as inconsistencies and difficulties of analyzing and coding students' discourse (Nielsen, 2013; Nussbaum, 2011; Roberts & Gott, 2010), inability to evaluate epistemic criteria (Duschl, 2007; Macagno & Konstantinidou, 2013; Sampson & Clark, 2008), and treating argumentation as product, not process in most of empirical researches (Kuhn & Udell, 2007; Macagno & Konstantinidou, 2013). There have been efforts to modify the analytic framework of TAP to cope with the limitations and examine the quality and process of children's reasoning and arguments (e.g., Sampson & Clark, 2008). However, argumentation as a process of reasoning and problem solving through children's conversation in classroom situations is not well understood. Given the theoretical and practical difficulties in the analysis of children's argumentation as structural constructions of thoughts or individual product, we pursue a different approach to understanding argumentation by focusing on think-*ing* and reason-*ing* through/in relations with others. We have chosen to take this route because of independently articulated claims that dialogue is the first instantiation of a new form of language (Bakhtin, 1929/1994; Vološinov, 1930; Vygotskij, 2005).

To theorize the emergence and development of argumentation, we ground ourselves in cultural-historical theories about dialogical relations as the foundation of instantaneous situational, individual (ontogenetic), and cultural change bringing together the work (Bakhtin, 1929/1994; Vygotskij, 2005). Although these scholars are sometimes held to pursue different lines of theorizing—dialectics vs. dialogism—they agree on fundamental grounds (Roth, 2013a). First, there is the supposition that all higher psychological functions *are* societal relations before these can be attributed to the individual (Vygotskij, 2005). That is, the relations with others in society-characteristic settings, such as schools, embody forms of knowing that we may subsequently find exhibited in the actions of individuals. This has the consequence that if

educators choose argumentative competency as a goal of their curricula, then children ought to participate *in* relations where argumentation takes place and where the relation itself *is* the argumentation. At the same time, the argumentation is *for* the relation, both in terms of the content talked about and for producing the social connection. In being produced, these societal relations transform and develop; and, together with the relations, those who participate transform and develop (given the relations are dialogical). Here dialogical is another way of saying that there are different ideas that evolve in confrontation with each other (Bakhtin, 1929/1994). This has as consequence that some conversations are not dialogical, including the late “Socratic dialogues,” because the truth is already given and the conversation is simply an expository genre for the articulation of a pre-established truth. On the other hand, even an internal monologue—such as those by the protagonists in Dostoevsky’s novels—may be dialogical because it confronts different ideas (Bakhtin, 1929/1994). In the same way, having two opposing judgments such as “Life is good” and “Life is not good” does not constitute a dialogical relationship and, therefore, does not constitute an argument, “although they can provide the referential material and logical basis for argument” (Bakhtin, 1929/1994, p. 397). On the other hand, two absolutely identical statements such as “Life is good” and “Life is good,” when expressed in “two statements by two different subjects, then dialogical relationships arise between them” (p. 398).

Argumentation emerges as, in/through, and for dialogical relations; a dialogical relation *is* argumentative. Argumentation is a particular genre, which, in the same way as the debate, is a medieval embodiment of the classical Greek dialogical menippean genre (Bakhtin, 1929/1994). Genres—as has been shown in the context of telling one’s life in the form of an Alcoholics Anonymous auto/biography (Lave & Wenger, 1991)—are learned by participating in their use. Because argumentation involves at a minimum two ideas that are confronted, we learn to argue in relations with others (Vygotskij, 2005), initially in informal ways and later in formal ways. This would allow us to understand why formal approaches to the teaching of argumentation often fail so that in classroom conversation where children participate in collaborative problem solving tasks, the process of making and justifying claims is often messy and non-linear and does not follow a structural order. In reaching a conclusion, there could be one piece of evidence, which is critical to classroom problems or forms of evidence that were not relevant to the problem. According to the structural framework, the latter is considered to be a good/high level of argumentation and the former as a low level of reasoning skills, and yet, the numbers of evidence do not justify the quality of argumentation. That is, coding or analyzing argumentation cores only cannot examine the dynamics of argumentation in the making (Macagno & Konstantinidou, 2013), for instance, how children encounter and resolve contradictions in their conversation and how argumentative discourse emerges and develops. A cultural-historical approach in contrast allows us to understand that the societal relation embodying argumentation has to exist prior to argumentation showing up as a higher psychological function, for example, when children *subsequently* speak or write for themselves in argumentative ways.

Dialogue is an integral and constitutive aspect of productive (societally motivated) activity, which mediates between the individual psychological and the societal dimensions of thinking and reasoning. This makes argumentation “inherently and irreducibly . . . a *collective* phenomenon” (Roth, 2013, A42, emphasis original). The emergence and existence of argumentation is only possible in/through relations involving speaker and hearer (Vološinov,

1930). A claim becomes a claim only when it is stated and responded to by the recipient. Evidence becomes justifiable only when the persuasiveness of it is experienced and acknowledged by an Other. Knowledge-building and decision-making emerge through argumentative relations (Berland & Lee, 2012). Thus, argumentation is the unit of collective talk and its quality is determined only by how those elements were used in the context of collective dialogue (Walton, 1996). This joint action of argumentation-*in the making* is irreducible to individuals' speech or their written responses. In a collective phenomenon, argumentation does not belong to individuals. It emerges and exists only at the collective level.

Important for curriculum theorizing, Bakhtin (1929/1994) explicitly links dialogism and argumentation: “[I]t should be noted that both relativism and dogmatism equally excludes all argumentation, all authentic dialogue, by making it either unnecessary (relativism) or impossible (dogmatism)” (p. 276). Authentic dialogue—the confrontation of different ideas in the communicative exchange between two or more people or the confrontation of ideas in the inner speech of a single person—is argumentation. Dialogical relationships exist when two statements, two judgments, come to argue with each other. But for this to happen, for the argument to unfold and develop as it strives towards a resolution, two antagonistic statements must be “separated into two different utterances by two different subjects” (p. 397). It is not juxtaposition in logically contradictory relations that makes an argument. Instead, true arguments only exist as dialogical relations, which exist when contradictory statements “clothe themselves in discourse, become statements, become the positions of various subjects expressed in discourse” (Bakhtin, 1929/1994, p. 397). In the sections that follow we provide a dialogical analysis of argumentation in an elementary classroom focusing on five important dimensions: (a) the emergence of problems and argumentation, (b) the individualization of collectively possible ideas and evidence, (c) the indeterminate unfolding of authentic dialogue that has a trajectory of a garden path laid in walking, (d) the resolution of contradictions inherent in argumentation, and (e) the appearance of contradictions simultaneous with the resolution of troubles.

Emerging problems, emerging argumentation discourse

Problems and problem statements do not just exist by themselves: they come into being. In the dialogical approaches of Vygotskij (2005) and Bakhtin (1929/1994), novelty comes into being in the encounter of people, and *as* their society-specific relation (Roth, 2013a). The adjective “dialogical” does not mean that there has to be dialogue—even a(n) (internal) monologue can be dialogical as long as different ideas come to be confronted in pairs of turns (Bakhtin, 1929/1994)—whereby statements (ideas) come to be confronted. How does a problem emerge in student–student conversations while making observation and explanation statements in science classrooms? In this subsection, we exhibit how “problems” (contradictions) *emerge* in classroom *conversations*.

In the following episode, children observe carrots floating when they poured salt into a water jar. Observing carrots floating, two girls (Niere and Eadon) started their conversation. The fragment begins with Eadon making an observation statement, the carrot is floating (turn 1-1), then formulates to have been right (which allows us to hear that she had hypothesized the observation before). Interrupted only by an invitation to keep stirring, she produces an explanation statement, whereby the disintegration of the salt allows it to be taken up by the carrot

“because the stuff that’s in the salt makes it float” (turn 1-3). She immediately starts to produce explanation statements concerning what happened to the salt and she expands on how the salt made carrots float (turn 1-3). The next statement begins with an oppositive conjunction “but,” followed by descriptive statements—the carrots soak up the salt, the salt goes into the carrots—which leads to the consequence that the carrots weigh more (turn 1-4). In this turn pair (1-3 | 1-4), we have two statements, two voices, that are logically contradictory. According to Bakhtin and Vygotskij, such contradictions are the nuclei of growth, because, at the level of the conversation, there is now a contradiction in the smallest conversational unit (turn pair). New ideas may emerge and develop in the course of subsequent turn pairs precisely because, at the level of the conversation, the joint action, the contradiction seeks resolution. Initially there is a pause, an opportunity for both participants to say something and, therefore, for the conversation to carry. The conversation continues statements that describe the salt in the carrots as making this “puff,” (perhaps in the way popcorn puffs when heated). Further conjectural statements make the case that the salt does not add much to the weight of the carrot. Again, in the resulting turn pair (turn 1-4 | turn 1-5), there are contradictory statements that come to be confronted, one stating that the absorption of salt increases the weight of the carrot, the other acknowledging the increase in weight but suggesting that this increase is compensated by the puffing up of the carrot.

Fragment 1

- 1-1 Eadon: Look our carrots are floating, and I was right... All the salt has to disintegrate.
 1-2 Niere: Keep stirring.
 1-3 Eadon: maybe the carrots soak the salt up.. and then they float because hum the stuff that’s in the salt, so that makes it float. ...
 1-4 Niere: But carrots soak salt, salt goes in the carrots, weigh more.
 (Pause)
 1-5 Eadon: If the carrots soak the salt in, maybe it goes “puff” so it makes it fluffier so it rises, because the stuff in the carrots, because with the, with the, there are not a lot of salt in the weight, there are not a lot of weight in the salt, so maybe it is because of the salt and the weight is not in the salt. So there is not lot of salt adds the weight.

As the conversation unfolds, ideas develop and new ones come to be produced. Conversely, as new ideas are stated and developed, the conversation unfolds. The relationship between the temporal unfolding of the conversation and the production of statements (their topics *are* ideas) is a mutually constitutive (dialogical) one. Here, “the problem” exists in and off the confrontation of oppositive statements in the minimum analytic unit of conversations, the turn pairs. The conversation unfolds, oppositive pairs of statements are created and, in the conversational striving for a resolution, the conversation develops with the creation of statements containing new ideas. That is, when we take the conversational turn pair as the minimum analytic unit, the interplay of contradiction and resolution is the “engine” that moves the conversation ahead and leads to the emergence and development of ideas. “Problem” then is another word for the inner contradiction within a single turn pair that expresses itself as a logical contradiction; and a resolution would consist in the emergence of turn pairs that no longer contain contradictory statements but agreements.

In this approach, we do not have to make “sharing” problematic, because saying that there is a problem and saying that it is shared are but two manifestations of the same phenomenon.

Because the category contradiction implies a unit of analysis that consists of a turn pair, the problem (contradiction) exists at the level of the *conversation*, which, inherently, is shared—or we would not be investigating a conversation at all. In fact, the dialogical approach suggests that the contradiction (problem) exists *in* and *as* the relation (Roth, 2013a; Vološinov, 1930). Here, the contradiction is reflected also at the level of the individual. This is so because when Niere speaks, the words are not only in her mouth and on her lips but these are also “ringing” in the ears of Eadon. Thus, if we take Niere for the moment as the unit, a contradiction exists between “the stuff in the salt makes the carrot float” ringing in her ear and the “but carrots soak salt, weigh more” that is coming from her mouth. That is, Niere’s turn begins while Eadon is speaking, with her active listening and transforming the statement; and it is to this heard statement that the her spoken statement responds, as in the following re-transcription of the turn pair from Fragment #1:

Fragment 1, retranscribed excerpt

1-3 Eadon (speaks): They float because hum the stuff that’s in the salt, so that makes it float. }

[1-3 Niere (listens): They float because hum the stuff that’s in the salt, so that makes it float

[1-4 Niere (speaks): But carrots soak salt, salt goes in the carrots, weigh more. }

[1-4 Eadon (listens): But carrots soak salt, salt goes in the carrots, weigh more.

[1-5 Eadon (speaks): If the carrots soak the salt in, maybe it goes “puff” so it makes it fluffier so it rises

To understand the dynamic of the conversation, the emergence of a contradiction (problem) and its conversational resolution, we need to consider turn pairs. In this way, the contradiction, problem, argument, or conflict exist not only between participants (curly brackets, right in fragment) but also within participants (square brackets, left in fragment). This situation led Bakhtin (1929/1994) to write that “it follows that only the unfinalized and inexhaustible ‘man in man’ can become a man of the idea, whose image is combined with the image of a fully valid idea” (p. 292). That is, in each statement we actually find two voices, where the speaking not only reflects what might be considered proper to the speaker but also her response to, and thereby uptake of, the speech of the preceding speaker (Bakhtin, 1929/1994; Vološinov, 1930). Conversational development strives towards the resolution of the contradiction, problem, argument, or conflict within the analytic unit (person, pairs of persons)—without any hope that such an endpoint will actually come to be. This is precisely why dialogical relations are inherently developing ideas that are finalized only when the dialogue has ended. In fact, Bakhtin (1929/1994) argues that the “idea is by nature dialogic, and monologue is merely the conventional compositional form of its expression, a form that emerged out of the ideological monologism of modern times” (p. 294). As a result, an idea, therefore, “is not a subjective individual-psychological formation that is ‘permanent resident’ in a person’s head” (p. 294). An idea inherently and irreducibly is interpersonal, intersubjective, a relation between individual concretizations of collective consciousness. It is out of the inherent dialogical relation between ideas that we obtain the emergence of the new so that even a single author of a statement (writer, speaker) cannot know in advance what she will have said when her saying has come to an end (Vygotskij, 2005): “The self-development of life is independent of the author, of his conscious will and tendency” (Bakhtin, 1929/1994, p. 286). This is so because every statement is a

response to a word that has come from the other, and, in speaking, is *for* the other and returns *to* the other. Every word is nothing for one but inherently and irreducibly a reality for two (Vygotskij, 2005).

Individualizing collectively possible (enabled) claims and evidence

In which way does language occur as language? *Language speaks*. . . . We leave speaking to language. (Heidegger, 1985, p. 10)

It is common to presuppose that human individuals speak to place into the public arena their earlier private cogitations or mental structures. However, any individual person uses language that precedes her. More importantly, anything a person can say is already made possible by language (Derrida, 1996), which is why “scientific misconceptions” are cultural and historical rather than individual phenomena (Roth, 2008). A person, therefore, only realizes what language already has in store; and, as such, anything that can be said already exists at the collective level (Vygotskij, 2005). Contrasting his approach to that chosen by Piaget, Vygotsky points out that children individualize the social rather than the (untamed, raw) individual being socialized into collective, cultural forms. In other word, when we talk (or write) it is language that speaks, as Heidegger describes it in the opening quotation. We leave speaking to language. In our speaking and hearing, the possibilities of language come to be individualized. This way of approaching language, therefore, turns upon its head the received presupposition that intersubjectivity is built in conversation: intersubjectivity pre-exists the individualization of a specific idea in two or more persons. In this section we exemplify how individuals (merely) realize argumentative forms always already existing as collective possibilities.

In the following episode, the contradiction of salt into carrots becomes more explicit in classrooms. The teacher reminds children of their idea which carrots are soaking salt (turn 2-1). Ellis says that he has different ideas (turn 2-2). His experience during an aquarium visit suggests that heavy objects can also float (turn 2-2), which the statement implies to be resolving the contradiction between adding weight into carrots and the results of floating. He saw a big heavy rock start floating when water was poured in the tank, whereas the lighter ones were going to the bottom. In fact, the statement produces an analogy. It does so in stating that “[Ellis] saw this,” where the indexical term “this” simultaneously refers to the carrots and whatever Ellis saw in the nearby town of Duncan. The teacher repeats (see underlined parts of turns 2-2 and 2-3) the statement but this time with rising intonation and with a grammatical structure that offers it up as question, “So the salt makes carrots heavier” (turn 2-3).

Fragment 2

- 2-1 Teacher: You do have the hypothesis that carrots are soaking up some of the salt, and,
 2-2 Ellis: I have different ideas, I saw this in Duncan ((nearby town)), at a . . . somewhere in Duncan, there's there's some small rocks around the big box, and if you can press a button, there was a bowl and the bowl gets filled up with water, if you press the button, then the, and then the lighter ones went down to the bottom and then the bigger ones and then heavier one went up to the top. So it could be because the salt is making the carrots heavier. So that helps them float.
 2-3 Teacher: So the salt makes carrots heavier?
 2-4 Ellis: <<piano>Heavier>.

- 2-8 Niere (says): That makes it sink.}
 2-8 Others (hear): That makes it sink.

Even if Niere had never stated such an inference and even if she had never thought about this phenomenon before, it comes to exist for her in and as the relation, and, therefore, also for her as and, possibly, for everyone else. Language itself makes the inference possible, just as it made the opposite inference possible. In both instances (i.e., for Ellis and for Niere), a collectively possible inference has been individualized in a concrete statement. However, we do not need to make inferences about what existed (objectively) for the participants. At the level of the conversation, the two inferential statements exist in the form of sound-words that are accessible to every person present. There is therefore a contradiction in the content. But for this contradiction to have any effect on the unfolding classroom talk requires that it be made apparent (Roth, 2013b). Language enables both but does not itself provide the criteria whether stating one is any more useful than stating the other (Rorty, 1989). This is a place where the teacher has an important function in classroom talk, because she can provide resources for making the contradiction salient publicly and, thereby, influence the future course of the talk. Whether this teacher takes up such an agenda and how she does requires further inquiry. At a minimum, this situation creates what educators have come to denote by the term “teachable moment,” where an opportunity for teacher moves and student learning arises. How this specifically might happen is articulated in the foundational role societal relations have in learning and development (Vygotskij, 2005). Thus, just as an inference may be first produced *in* and *as* relation (i.e., turn 2-7 | turn 2-8), a contradiction may be made salient in turn pairs involving the teacher and students. But the framework articulated here also makes it evident that the teacher has no control over whether the contradiction actually comes to be taken up as the issue in and by the conversation. Because she does not know what students will state in the turns following her own, the conversation may never follow the path she might have intended it to take (Wagenschein, 1977).

In this fragment, a contradiction comes to be articulated between two statements concerning the floatability of carrots that have become heavier when soaking up salt. The contradiction comes to exist almost despite the individual participants. It comes to exist at the level of the conversation, which is a social rather than an individual phenomenon. Every word said, every statement uttered, implies its intelligibility. In fact, even a non-intelligible statement can be recognized only against the intelligibility of other statements and, therefore, presupposes mutual intelligibility (e.g., Roth, Lee, & Hwang, 2008).

In Fragment 2, the teacher-produced statements in turn 2-3 and turn 2-6 have the function of pulling out and making more salient some of the possible topics, here, ascertaining just what is being asserted in the conversation about the relation between the salt added to the water and the carrots. The conversational development of the topic is produced in the sequentially organized turn-taking sequence and irreducible to the individual. The children make statements, which the teacher takes up and reproduces in part. Without the children’s contribution, the teacher would have nothing to take up; and without the teacher’s contribution, some pedagogically interesting developments might not occur. Rather than theorizing this situation as an *interaction*, as many received approaches tend to do, we take up the Bakhtinian and Vygotskian agenda of theorizing classroom talk as a social phenomenon that cannot be reduced to the individual participants. Teacher and students, thereby, are not only individual subjects contributing to the unfolding talk

but also are subject to and subjected to it. In this, they produce the very context that determines what they can and cannot do, because one “person accepts to engage in the dialogue, his life situation is temporarily transformed” (Rommetveit, 1974, p. 23). Because of this transformation, even the best science and mathematics teacher working from a dialogic (early Socratic) perspective cannot anticipate where the conversation is going (Wagenschein, 1977). But precisely because truly dialogic classroom conversation takes up where children are in their ways of talking about the world, there are opportunities for their new forms of talk to emerge genetically from their old forms of talk. In other words, children remain rooted in their familiar world. We see this at work in the continuation of the episode, when Ellis is given the opportunity of another go at describing what he has seen in the nearby town.

Laying the garden path in walking

I shall be telling this with a sigh / Somewhere ages and ages hence:
/ Two roads diverged in a wood, and I— / I took the one less
traveled by, / And that has made all the difference. (Robert Frost,
The Road not Taken)

In the famous poem about the traveler at the crossroads where he has to take one of two roads, Robert Frost makes him go down the less traveled one and concludes that it has made all the difference. It has been recognized that in science and mathematics lessons that really take into account children’s experience and foster dialogical relations, even the best teachers cannot anticipate where the classroom talk is taking them and their students (Wagenschein, 1977). But in whichever way the conversation is unfolding, and whichever untrodden path it is taking its participants, some time “ages and ages hence” they will be able to say that it is that turn “that has made all the difference.” In this section we show how any one instant in classroom talk may be taken as a teachable moment which made something salient and worth learning.

Of the many possibilities to respond to the situation, the next statement (i.e., the teacher’s) does not take up the question about the salt and carrots. Instead, another statement (i.e., Ellis’s) provides an opportunity to pick up on the question about heavier and lighter objects that sink or float. The teacher says, with rising intonation that allows us to hear a question, whether it [the rock?] was really heav[ier] or whether it was bigger than the other rock (turn 3-2). Quietly and hesitatingly, Ellis states that he does not know and adds, “it was a cage” (turn 3-3). The next teacher statement does not actually take up on what Ellis has said but constitutes a comment on and evaluation of what his statement has done: brought in evidence for what he has thought. The teacher, thereby, is telling not only Ellis but everyone else listening that what Ellis has done is providing evidence, which is an important dimension of argumentation. The remainder of the statement is drowned out by another one (Oonagh’s) that directly contradicts what Turn 3-1 has proclaimed. The contradiction is made apparent in the use of the contrastive conjunction *but*. The next turn begins with the conjunction *because*, which articulates a reason for whatever precedes and linked to it. Here, the reason pertains to the characteristic of little rocks compared to bigger rocks: these are lighter.

Fragment 3

- 3-1 Ellis: In Duncan there is a heavy box of metal. And then there is a lighter box around it ((gestures “around” with hand/finger circling)) and then when it got— and then . . . and they were in a boat and when you press the button they would get filled up and the heavy ones floated and the lighter one sank.
- 3-2 Teacher: Was it really heavy, or was it bigger than the other rock?
- 3-3 Ellis: <<p, hesitatingly>I don-know um> . . . it was a cage.
- 3-4 Teacher: I like the you are trying to bring in evidence for why you think that [but I thought (it didn’t match?)]
- 3-5 Oonagh: [But the lighter ones should] float and the bigger ones should sink. (1.5)
- 3-6 Naire: Because littler rocks are lighter than great, bigger rocks.

Again there is an aspect of argumentation instantiated across a pair of turns. Turn 3-5 states a claim: lighter rocks should float and bigger rocks should sink. This turn is paired with Turn 3-6, which provides a reason for why “littler” should float: because these are lighter than bigger rocks. That is, this form of compound statements in which a claim is made and a reason is provided arises *in* the relation of two students. It also exists *as* the relation, because the turn pair also establishes (continues) the relation. The students relate precisely because they co-participate in the unfolding talk. This is the crux of the point Vygotskij (2005) makes, but which is infrequently taken up in a body of scholarly literature that tends to emphasize the occurrence of certain “psychological functions” *in* the relation students have with others—not only more advanced teachers and peers but also with any other peer who might be equally or less advanced (Roth & Radford, 2010). It is in this relation that a “zone of proximal development” is created because the children themselves produce the argumentative pattern “«claim» *because* «reason».” When a child such as Oonagh or Niere, who previously produced part of this pattern in relation with another subsequently produces such patterns on her own, we would have evidence that participation in the relation has changed the ways in which they contribute to argumentative forms of classroom talk. In Ellis’s earlier statement “So it could be *because* the salt is making carrots heavier . . . that helps them float” this pattern is already observable in a statement by a single speaker.

The other important aspect observable in this fragment is the *formulation* of what has been done. In the same way that we have to be able to speak a language before having something that we can grammaticalize, we need to be participating in or familiar with argumentation before we can learn its grammar. *Formulating*, a technical word from conversation analysis that denotes the practice putting in words what is or has been done (Garfinkel & Sacks, 1986), is put to pedagogical use in naming and thereby making stand out what a child has done as something special and, perhaps, as something to be repeated. It is like naming parts of speech when children first encounter grammar during their elementary school years. In argumentation, the role of evidence is critical to strengthen arguments or claims. Evidence is a critical tool to evaluate claims and persuade others. We observe that the children produce these aspects spontaneously because of the possibilities language itself offers. However, producing the statement forms that are fundamental to argumentation is not enough for more knowledgeable participation in argumentation. As Vygotsky (2005) suggests, culture enters when among all the actions of children parents (or teachers) select and, in their responses, take up some. Vygotsky uses the example of how small children learn to intentionally point: Parents take a child’s failed grasp as an instruction, pick it up and reach it to the child who, once this has occurred a number of times,

begins to point intentionally. In the present instance, Ellis has done something that is an important part of what our culture recognizes to be argumentation. It is through the teacher's statement in turn 3-2 that this aspect comes to stand out and that it subsequently can become an *intentional* aspect in the children's participation (Vygotskij, 2005).

A final important aspect is the generation of uncertainty. As some authors have suggested, uncertainty is an important dimension of the development of conversational topics because it offers opportunities for exploring alternative possibilities of establishing just what a statement has said (Roth & Middleton, 2006). We might gloss what is happening in the opening of Fragment #3 in this way.

- 3-2 Teacher (says): Was it really heavy, or was it bigger than the other rock?
 3-2 Ellis (hears): It might not be really heavy bigger than the other rock | Was your observation really correct?
 3-3 Ellis (says): <<p, hesitatingly>I don-know um> . . . it was a cage.

Even though we do not know what Ellis hears, the subsequent statement in turn 3-3 has been shaped by what he has heard and, therefore, by what the teacher has stated (Vološinov, 1930). The recipient actively orients toward the speech of another and thereby prepares for the actual reply, which, thereby, reflects not only the speaker but also the preceding speaker whose statement has been taken up (Volosinov, 1930; Waldenfels, 2006). In the pairs of turn 3-2| turn 3-3| turn 3-4, there emerges a certain level of uncertainty, doubt or hesitance toward Ellis' evidence and it become salient and recognized by others. Ellis's hesitant reply was not only paired with the teacher's question but also with the collectively produced counter-statement according to which lighter or smaller objects should float. This sequence created uncertainty about just what it was that the statement proclaims to have seen and thereby weakened the possible contribution of the "evidence" of turn 3-1 brought into the conversation. That is, the turn pair turn 3-1 | turn 3-2 produces evidence of literally questionable nature. At the level of the conversation, its impact is weaker than it would have been had turn 3-1 been paired with an endorsement.

Resolving contradictions

Argumentation is a dialogical process where different ideas are in confrontation, leading to a continuous unforeseeable evolution towards a resolution of the differences (Bakhtin, 1929/1994). The moments of confrontations emerge and then are resolved and are revoked by the conversational dynamics which no one could predict on how it would unfold. The uncertainty and tension around confrontations opens up avenues for new ideas, new claims, and new questions that moves the overall activity ahead (Roth & Maheux, 2013). In the previous fragments, there were instances of confrontation in the conversation around the contention that salt makes carrots float confronted by the idea that salt makes carrots heavier. Although individual students may have actually stated the claims with their mouths, these were claims only because they were simultaneously received in the ears of the other. The claims and counter-claims, therefore, do not belong to individuals. The argumentation is a public event to be witnessed by all those present. The individuals only stated what was possible and intelligible and, therefore, pre-existed the individual speaker. There was also tension surrounding the

narratively provided evidence concerning the floating of heavier rocks and the sinking of the lighter rocks. This narrative challenged and was challenged by a subsequent statement according to which heavier objects cannot float. In this section we provide an account of how the situation comes to be resolved while revoking the contradiction into another direction.

In the following fragment, the tension arising from the narrative about the sinking and floating of heavy and light rocks received further like by another narrative pertaining to the same aquarium. Kaedon states to know the reasons for the earlier narrative, a fact that the statement attributes to speaker's own experience of having been to the aquarium (turn 4-1). In this turn, we do see the kind of argumentative structure in the same statement in the way that the teacher formulates as a desirable structure: The statement contains a claim—"I know why Ellis is saying"—and concludes with the articulation of a reason. Evidence is provided as the statement unfolds: holding the "big rock" reveals that it was made of plastic. In the exchange that ensues, the conversation brings to the fore that the "big rock" floats while the smaller ones sink when water is added. Again, we observe the "«claim» *because* «reason»" pattern play itself out *across* speakers (e.g. turn 4-4 | turn 4-5). That is, just as Vygotskij (2005) suggests, this pattern characteristic of argumentation exists here *in* the relation; and, because talk constitutes the relation, the pattern exists *as* relation. It also exists *for* the relation, as every speaking turn produces talk for the other in response to something that has come from the other.

Fragment 4a

- 4-1 Kaedon: I know why Ellis is saying that bigger one was floating because I've been there too. You could hold the rocks, and the big one was actually plastic.
- 4-2 Teacher: Oh, so it looks like a big heavy rock, it's sitting in the middle,
- 4-3 Kaedon: Yea.
- 4-4 Teacher: and it floats when you add water, and the other things sink to the bottom even though they look smaller,
- 4-5 Kaedon: Ya, because plastics are actually lighter than actual rocks.
- 4-6 Teacher: But I like how you are using evidence, because you said you saw a heavy rock floating in the water but now we know it wasn't really rock, it was made out of plastic, was tricking us.
- 4-7 Ellis: Yap. err, can I get some water?

The talk provides markers to exhibit that "providing evidence" is desirable. In the highlighting something like an intention, in the same way as before the teacher *formulates* that what Ellis had done was providing evidence. That is, not only Ellis but all the others have seen the practice of "providing evidence" in the immediately preceding action. Turn 4-6 uses the verb "to like" in transitive form, the object being the use of evidence. There is a further elaboration just what the evidence consisted of: seeing the heavy rock floating and knowing that it was not a real rock. That is, in this statement we observe a retrospective denotation as a prior turn to have provided evidence, and a re-articulation of precisely in and as what the evidence consisted of. The statement further articulates possible problems with evidence of observational nature: observation can be tricked, and this weakens it as evidence. This turn shows that the previously stated observation was not wrong but incomplete with a missing part that was not revealed to the observer (Ellis) at that time. This is another process of *formulating* the importance of using evidence and further the importance of complete and thorough observation as evidence in dialogical argumentation. When observation as a way of data collection is not complete or

accurate, it is not strong evidence and cannot support any arguments based on it. Ellis' observation was completed and became evidence *in* and *through* the relation with Kaedon. By putting the two pieces of information together, the statement makes the important relationship between observation and evidence, and argument salient and public.

In this turn 4-6, there is a generation of inclusivity. The phrases, “*now we know*” and “tricking *us*,” whereby the language designates those present to be part of a larger unit engaged in the process of constituting the intelligibility of natural phenomena. Although the statement may have been unrelated to the framework elaborated here, it is in fact consistent with the observations and explanations that we provide: the *conversation* is an irreducible *social* phenomenon that needs to be treated as a *social* fact (Durkheim, 1919). The confrontations among the observation, evidence, and claim emerge in relations of the entire group, children and teacher. The account of the aquarium visit that Ellis articulates experience became contradictory only when it was confronted with the idea that heavier objects sink. For the purpose of the unfolding conversation, it does not actually matter that Oonagh has physically produced the statement, for it would not have had an effect on the conversation had the statement not simultaneously resonated in the ears of the recipients (Roth, 2013c). The contradiction does work as contradiction only when it operates at the level of the conversation, the dialogical relation, where it belongs speakers and recipients, that is, to the group as a whole (Vološinov, 1930). It is precisely because argumentation is a demonstrably public affair, where its different parts—contradiction, evidence, or claims—can be pointed to, formulated, repeated, and explicitly shown in their functioning that children participating in such situations learn to argument. It is not, however, that they somehow internalize what has happened before publicly: their own concrete and public contributions presuppose relevant processes that reflect the outer ones on an internal plane.

Resolution leads to reoccurrence of trouble

In the preceding section, we show how a contradiction comes to be resolved. But the resolution of contradictions does not mean that these disappear. In fact, the theory of emergence suggests that at any point novelty is produced that could not have been anticipated on the past history of a conversation (Roth & Maheux, 2013). Thus, at any point in classroom talk, new contradictions can and often are likely to emerge. This is not a negative aspect of classroom talk but rather constitutes the very generativity that affords opportunities for learning (children's changing participation in changing practices (e.g., Lave, 1993). In this section we show this also to be the case in the present whole-class conversation concerning the floating of carrots when salt is added to water.

The classroom talk around the evidence on the plastic object resolved the tension of uncertainty; but it also brought back the contradiction on floating carrots to the whole class. The statement that the floating object was plastic suggested that light objects float and heavy ones sink. This confirmed the early claim on heavier means sink. The contradiction among “heavier means sink | carrots soaked salt and got heavier | carrots floated” came into the conversation and led the whole class once again back to the question, “why did the carrots float?” Another opportunity of claim making was suggested (turn 4-10). Teacher states if children have completely different ideas. Kaedon suggests Ellis might have meant to say that salt was making

carrots *lighter* (turn 4-11). Then the teacher responds, “*so you think* that salt is making carrots lighter” (turn 4-12) and Kaedon replies, “yes” (turn 4-13).

Fragment 4b.

4-10 Teacher: Do we have another completely different ideas?

4-11 Kaedon: When Ellis used.. just said, maybe the salt is making carrots lighter.

4-12 Teacher: So you think the salt is making carrots lighter.

4-13 Kaedon: Ya.

What Ellis spoke about the floating rock was heard in class. Kaedon heard the speaking and explained what he thought of the speaking. Once a word is spoken by a speaker, it is resonated and completed by other end, a hearer. Through the hearer’s response, the speaker’s speaking is finally completed. The hearer her/himself also processes her/his own thinking through responding that s/he speaks. Kaedon as hearer hears what Ellis says. And, he as a speaker speaks what he heard and thought. He states what Ellis might mean was salt made carrots lighter. The teacher as hearer hears it and speaks what she heard (*Kaedon* thinks the salt is making carrots lighter). A new claim, salt makes carrots lighter was made. This claim making was only possible through the joint social action of conversation. Throughout the conversation, the sense making of the speaker is completed only by the hearer’s hearing and follow-up speaking. The transaction of speaking and hearing is dialogic and irreducible in terms of meaning making. The statement, “*so you think*” takes up Kaedon into the claim making. Kaedon himself only hears what he thinks through the statement. The claim making comes through the intrapersonal level first and the intrapersonal later.

Instead of carrots getting heavier, now carrots get lighter by salt. This new claim leads another question of how salt makes carrots lighter. Cooper suggests that salt was eating up the carrots (turn 5-1). Teacher uses the word, “dissolving” to replace “eating up” (turn 5-2). Salt dissolves part of carrots is becoming their new claim for the next step of problem solving.

Fragment 5

5-1 Cooper: I think the salt is eating the carrots.

5-2 Teacher: Like dissolving the carrots?

5-3 Cooper: Ya!

5-4 Teacher: A little bit? That’s a hypothesis, then?

5-5 Children: Yes.

5-6 Teacher: That, the salt dissolves part of carrots?

5-7 Children: Yes, yes.

The process of claim making constitutes not only the “unity of thinking and speaking but also the unity of generalizations and intercourse, of communication and thinking” (Vygotsky, 2005, p. 676, original emphasis). The claim making (salt was soaked into carrots → salt made carrots heavier → salt made carrots lighter → salt dissolved part of carrots) was possible only through conversation where children and teacher interdependently attributed to the classroom problem solving. Sense making as collectives derives from the fact that in communication of something, a feeling, belief, or content of consciousness, there is no other way than attributing the content to a class of phenomena” (Roth, in press, A47). There were several moments of resolving and

revoking contradictions and tension through problem solving process. Claims and forms of evidence were supported and interrupted by counter-claims and forms of evidence. The moments of contradictions were positive and necessary to move forward toward problem solving. Children and teacher are situated collectively and dialogically in the problem solving process and the dynamics of different ideas, evidences, and feelings developed argumentative discourse to move forward toward alternatives and solutions.

Discussion

This study was designed to articulate a different route to describing and theorizing the trajectory of changing participation in scientific argumentation (i.e. learning). With a widespread emphasis on teaching argumentation as a way of developing children's scientific thinking and problem solving, educators and researchers have studied on how to teach and evaluate children's argumentation skills in science classrooms. Yet, the current approach to children's argumentation has resulted in some concerns about theoretical and practical difficulties in analyzing children's argumentation. That is, argumentation is taken as individual and structural product not a process, which lacks the understandings of epistemic criteria and dialogical nature of collective argumentation. In this study we propose a different approach to examining children's argumentation based on the theories of Bakhtin and Vygotsky. This approach emphasizes that the origin of internal dialogue and higher psychological functions are inherently embedded in societal relations where argumentation takes place (Vygotsky, 2005). In this framework, argumentation exists *as* and *for* the relation as it exists *in* the relation. Language speaks and precedes thinking, thus, without engaging in dialogical relations, there is no argumentation discourse (Bakhtin, 1929/1994). To understand dialogical process of argumentation, this study investigated how second-/third-grade children participated in science classroom talk and how argumentative discourse emerged and developed in, for, and as relations. Rather than understanding argumentation as a change in individual student talk and writing, we investigated the place where argumentation first appears: in collective and dialogical reasoning processes.

Argumentation as social joint action

Based on the analysis of fragments science classroom talk, we showed how argumentation emerges and exists in and as a joint social action. Argumentative discourse such as contradiction and problem situating, claim making and evidence evaluation emerged and developed as children actively participated in speaking turns. For example, when Eadon and Niere were talking about their observation on floating carrots, the phenomenon of floating carrots became problematic. When Eadon stated the salt was soaked into and made carrots float, Niere responded, "*but . . . weigh more.*" A contradiction between floating and weight was emerging in the turn pair of Eadon's speaking and Niere's responding. A problem (contradiction) was not a problem prior to children's speaking turns or prior to their making an issue of the real problem to be talked about. The contradiction is stated, felt, and situated through children's verbal interactions and orienting them toward argumentative discourse. This moment of evolving a problem is critical in argumentation discourse. It situates children in the problem of logically contradictory statements, a crucial basis of argumentation (Wagenschein, 1977). Another example of argumentation as

joint action can be seen in the episode of floating rock. Ellis and Kaedon were explaining their experiences on a floating rock in water tank. Through the conversational engagement, the weight of carrots became a salient problem. Different evidence was given, evaluated, rejected, and accepted throughout the dialogue and a new claim was created to respond to the contradictory problem. It is in the different positions, in the different voices, that the problem first comes to exist. These different voices are precisely what Bakhtin (1929/1994) describes as the core of the dialogical process that leads to the evolution of ideas. Our analysis therefore is ethnographically adequate in the sense that it shows where the argumentation *first* becomes visible: *in*, *as*, and *for* the relation. Every turn pair is a social joint action which shows how argumentative discourse (claim making and evidence evaluating) was collectively processed and developed. Any claim made came about through a joint evaluation of evidence. The irreducible and inevitable nature of collective argumentation engenders the need of different approach to teaching and understanding children's reasoning and argumentation.

The emergence of tension, developed argumentation

It has been suggested that "events can be distinguished only because emergence is always there to impose presence before us" (Roth & Maheux, in press). The tension of argumentation always exists in problem situations and it comes into our consciousness only through dialogues. This study shows certain levels of tension through the development of argumentation. The emergence of tension and the tension of emergence was a driving force to children and teacher to develop argumentation. There were moments of tension emerged and recognized in children's conversations. Such tensions first exist in turn pairs, such as in the "but . . . weigh more" and the revision of an earlier statement as "puff." This tension at the level of the conversation situates children in the emerging contradiction. The individuals, such as Eadon and Niere are only protagonists in a tension that exceeds both of them before their individual statements include such tensions as points of development. There was also tension in evaluating evidence around the floating rock. The *contradiction* between the heavy rock rising or sinking *first* existed at the collective, conversational level. We may perhaps at some later time find one or the other participant deliberating on their own in the way the deliberation here occurred involving several of them. That is, any form of argumentation may arise at the level of the conversation and then may show up when the same individual takes on those previously distributed parts of the argumentation.

The tension of emergence, teaching argumentation

There is another type of tension in a pedagogical dimension as children's argumentation develops. As the theory of emergence suggests, argumentation emergence to take a path that even the best teachers—if they are concerned with children's understanding—can anticipate (Wagenschein, 1977). It is a common practice that teacher participates in class discussion to scaffold children's ideas and achieve intended learning outcomes. Despite teachers' specific (by the official curriculum mediated) expectations for what children should do and achieve through classroom conversation, the emergence and development of argumentation depend on the dynamics of conversation, over which she does not have control. As Bakhtin (1929/1994) suggests, even the authors of truly dialogical novels (e.g., Dostoevsky) are not in control over their protagonists' speech, which contingently evolves in response to the changing nature of the

conversation. This nature of emergence and collectives in argumentation brings pedagogical challenges in classroom teaching, consistent with the claims that true learning cannot be planned in an administrative manner (Holzkamp, 2013). How can teachers set up an effective environment to teach argumentation in classrooms? This study shows that the tension of emergence was fundamental to bring forth teachable moments. The teacher in this study encountered several moments of unexpected turns of speaking and responses from children and she did not/could not do much either to change children's statements or to solve contradictions from their speaking turns. She could only repeat words, raise questions, or make comments on children's statements. However, through these participations, she could bring significant moments of *formulation* on argumentation in the discussion. Rather than emphasizing correct claims or evidence, she stated that she liked Ellis using evidence to back up his claim. She formulated what Ellis did was using evidence in the discussion and how important it was in scientific problem solving. The actions of backing up with evidence and evaluating the accuracy of evidence came into being and appreciated as important aspects of argumentation in the making only through teacher's formulating statement. This suggests an important way of teaching how to develop a good argumentation. By participating in children's conversation, teachers point out the moments of argumentation in the making in order to develop children's reasoning and argumentation skills.

Coda

In this study, we suggest that learning argumentation as collective dialogical process emerges in and through participation in collective dialogue. Children learn how to make claims, how to evaluate evidence, and how to justify explanation only in and through social relations of speaking and responding. This means teaching and learning argumentation starts in public settings first, where they have opportunities to changing participation in changing (argumentative discourse) practice (i.e., to learning). Rather than engaging children in individual writing to learn argumentation structures first and to participate in argumentative discourse later, this study suggests that we might teach argumentation by inviting children prior to attempting the development of individual argumentation "skills." This suggests a fundamental shift in the current view of examining children's argumentation abilities at individual levels. Argumentation is not an individual product but a collective process that subsequently comes to be individualized. Further studies are required for studying possible support mechanisms, for teachers and students alike, to optimize the changing participation in changing argumentative practices so that this subsequently might be observable in the ways individual students construct arguments about scientific matters.

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