International Journal of Science Education

ISSN: 0950-0693 (Print) 1464-5289 (Online) Journal homepage: http://www.tandfonline.com/loi/tsed20

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To cite this article: Mijung Kim (2016) Children's Reasoning as Collective Social Action through Problem Solving in Grade 2/3 Science Classrooms, International Journal of Science Education, 38:1, 51-72

To link to this article: http://dx.doi.org/10.1080/09500693.2015.1125559

Published online: 22 Jan 2016.

INTERNATIONAL JOURNAL OF SCIENCE EDUCATION, 2016
VOL. 38, NO. 1, 51–72
http://dx.doi.org/10.1080/09500693.2015.1125559

Routledge
Taylor & Francis Group

Children's Reasoning as Collective Social Action through Problem Solving in Grade 2/3 Science Classrooms

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ABSTRACT

Research on young children's reasoning show the complex relationships of knowledge, theories, and evidence in their decision-making and problem solving. Most of the research on children's reasoning skills has been done in individualized and formal research settings, not collective classroom environments where children often engage in learning and reasoning together to solve classroom problems. This study posits children's reasoning as a collective social activity that can occur in science classrooms. The study examined how children process their reasoning within the context of Grade 2/3 science classrooms and how the process of collectivity emerges from classroom interactions and dialogue between children as they attempt to solve their classroom problems. The study findings suggest that children's reasoning involves active evaluation of theories and evidence through collective problem solving, with consensus being developed through dialogical reasoning.

ARTICLE HISTORY
Received 13 May 2015
Accepted 24 November 2015

KEYWORDS
Reasoning; Collective Dialogue; Elementary Children; Problem Solving

A Rationale of the Research

Children's Reasoning in Collective Dialogue

Students draw inferences or conclusions based on their prior or situation-at-hand knowledge, information, and experiences in given situations. For instance, when they see dark clouds in the sky, they may predict it might rain later based on their experiences and prior knowledge. They interpret a phenomenon to make sense of it; that is, they are *reasoning* through the situation at hand. Mercier (2011) distinguishes reasoning as reflective inference from intuitive thinking, which involves spontaneous and intuitive interpretations and actions. Intuitive and reflective inference can be explained with the following example: when we enter a subway station and look at people standing by, we simply assume that they are waiting for a train. This is an example of intuitive inference, which does not involve much of the thinking process to understand the situation. Yet, if we see police officers looking serious at the station, we start questioning why the police officers are there. This process requires reflection on relevant knowledge and relies on our ability to connect that knowledge to the situation around the police officers

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at the subway station. Mercier points out that the latter inference is reasoning that requires more of the thinking process to infer relationships between phenomena, such as cause and effect, and better understand situations at hand. The two types of reasoning—inference from intuitive reasoning and reflection on relevance knowledge at the specific situation—have also been thoroughly described in the discussion of dual process and dual systems theories, for example, System 1 and System 2 thinking (Kahneman, 2011) and type 1 and type 2 process (Evans & Stanovich, 2013). According to Kahneman, System 1 thinking is fast, automatic, and intuitive with no or little effort; System 2 thinking is slow, effortful, and complex. He provides examples of System 1 thinking: 'read words on large billboards' or 'drive car on an empty road'. Examples of System 2 thinking include, 'search memory to identify a surprising sound' or 'check the validity of a complex logical argument' (pp. 21–22). In recent years, the terms (System 1 and System 2) in dual systems theories have been challenged by some scholars (e.g. Evans, 2008; Evans & Stanovich, 2013) that the term, 'system' is ambiguous as it can sometimes act as a synonym for a two-minds hypothesis and the term such as System 1 or heuristic system, is being used as a singular system, which should be actually plural as a set of systems (Evans & Stanovich, 2013). Evans and Stanovich (2013) suggest the term, 'types' to explain the complexity of reasoning process. They explain type 1 process is autonomous and does not require working memory and type 2 process requires working memory with 'cognitive decoupling: the ability to distinguish supposition from belief and to aid rational choices by running thought experiments' (p. 236). Despite the current debates between systems and types of dual process theories, it is agreeable that there are two levels of thinking process; one is fast, autonomous, and intuitive with no or little effort (intuitive thinking hereafter); the other is slow, reflective effortful, and complex (reflective thinking hereafter). Intuitive thinking automatically and continually runs and generates suggestions for reflective thinking with impressions, intuitions, intentions, and feelings, and reflective thinking evaluates these suggestions to solve the problems of a moment (Evans, 2003; Kahneman, 2011). That is, even though intuitive thinking always supports reasoning and decision-making, reflective thinking is necessary to evaluate ideas with working memories and reach better conclusions. Logical and hypothetical reasoning process through reflective thinking has been emphasized in science classrooms to improve students' scientific thinking, hypothesis making, and decision-making (Lawson, 2004). The effort of reflecting on relevant knowledge, cases, and experiences is the activity of looking for and evaluating available information, evidence, and knowledge.

To develop children's scientific thinking skills in science classrooms, there have been efforts to emphasize children make claims-based scientific knowledge and evidence. Kuhn (1989) explains, 'the heart of scientific thinking is the coordination of theories and evidence' (p. 674). When scientists encounter a question or puzzling situation, they analyze the context of question and situation, look for supporting and contrasting evidences, accept and articulate a theory, and justify why the coordination of available theories and evidence has led them to accept certain theories and reject others. Even though students do not adopt all of the scientists' thinking processes, they tend to coordinate their knowledge and evidence to understand the situation at hand. When students critically examine claims, have a cluster of reliable evidence that may include examining abnormal phenomenon or outliers in data sets, and analyze the covariation between what is observed (data) and theories, they may feel confident to accept the proposed claim/theory. Good scientific thinking and reasoning includes abilities to provide a better explanation of given problems based on the dynamics of accepting and rejecting theories and evidence.

Reasoning can be processed individually as well as collectively. As the example of the police officer at a subway station illustrates, based on their prior knowledge and experience, individuals can determine their own reasons why the police officer was there by observing the officer's actions in relation to the specific situation. Even if such reasoning cannot be entirely separated from the social realm, it could remain part of an individual's thinking until that person engages in dialogical interactions with others. When others at the scene explain to him or her that they saw the police officer investigating a suspicious bag earlier, the individual's reasoning gets challenged by the new piece of information. Our reasoning goes beyond individual intuition and inference. Through dialogical interactions, reasoning becomes a social activity. Given that collaborative decision-making skills are a critical aspect of scientific literacy for the current and future society, it is important to understand children's reasoning as collective social actions in classroom situations. After all, no one expertise or discipline can solve complex problems that we face in our lifeworld situations.

The notion of collective reasoning is supported by research on children's learning and knowledge as collective (Mercer, 2008; Mercer, Dawes, Wegerif, & Sams, 2004). Learning can be contextualized within shared frameworks of knowledge constructed through shared reasoning as learners collectively signify and justify their interpretation of observed phenomena through the dynamics of diverse information, evidence, and communication (Kim & Tan, 2013; Mercier, 2011). It is only through these social interactions that the collective understandings of problems, knowledge, and application can be reached. Thus, in collective reasoning, students are engaged in discussing different claims and explanations to persuade others and find the best solutions to any given problem they encounter. Mercer et al. (2004) found out that children's exploratory talk during collaborative discussion helped children share relevant information and negotiate ideas to reach an agreement before taking a decision or action on their problems. These collaborative reasoning and discussion-making processes develop children's intellectual capabilities to think and reason (Clark et al., 2003). Thus, given that children's problem-solving and critical-thinking skills will be essential to solving world problems in the future, it is important to understand children's reasoning as a cognitive social process in dialogical problem-solving contexts.

Young Children's Reasoning and Dialogical Explanation

As children go through several developmental stages, their reasoning abilities and processes are expected to develop both cognitively and socially. The ability of secondary students to process their reasoning and problem solving would be more advanced than what young children are capable of, particularly in terms of their sophistication of data examination and coordination with different claims, hypothesis, and theories that they and their peers might generate. Adults and older students would exhibit more critical examination of any existing data or evidence that conflicts with their claims and, as a result, are more willing to explore alternative hypotheses, whereas young children often overlook conflicting data and show preference to positive data to test hypothesis (Klahr & Dunbar, 1988). To understand young children's (K-3) reasoning abilities, researchers (e.g. Kuhn &

Pearsall, 2000; Metz, 2011) have explored children's ability to infer and explain their rationale for claims during problem-solving tasks and investigated how children coordinate theory and evidence. For instance, Kuhn and Pearsall (2000) found out that young children (4 years old) often mixed up their answers between evidence (data) and theory (knowledge). They suggested that children at an early age did not recognize the difference between theory and evidence and often interchanged these within the context of whole explanations. As a result, in many cases, when children observe something that confounds their existing theories (prior beliefs or knowledge), their ability to process the covariation of data from their observation often becomes conflicted (Croker & Buchanan, 2011; Koslowski & Masnick, 2011). Because of this, research into how children might develop consistency and consilience between theory and evidence becomes a meaningful pedagogical question in classroom learning.

Other researchers, however, argue that young children are capable of interpreting observation and doing scientific investigation and reasoning as scientists do (e.g. Kuhn, 2011; Metz, 2011; Zimmerman, 2007). The results of earlier empirical research in this area suggest that young children have an ability to use the covariation of events as an indicator of causality and discriminate indeterminate situations from determinate ones. For instance, Schulz, Goodman, Tenenbaum, and Jenkins (2008) suggested that preschoolers (on average 57 months old) could distinguish interventions from observed correlations in causal structures and could infer abstract casual laws with sparse data by manipulating a few colored blocks in their study. These studies emphasize that young children are capable of making relations between evidences to understand certain phenomena. That is, they have the ability to evaluate covariation and non-covariation evidence in causal reasoning processing (Piekny & Maehler, 2013). Metz (2011) studied first graders' thinking at three levels of reasoning suggested by Driver, Leach, Millar, and Scott (1997): phenomenon-based (observation), relation-based (correlations among variables and cause and effect), and model-based (theoretical models beyond observation or variables) reasoning. In her research, many of the first graders could make relation-based reasoning based on variables and use evidence to draw a conclusion. Children become capable of scientific reasoning by making causal relations and developing connections between theories and evidence throughout school years, even though the coordination of theories and evidence might be more challenging at early elementary grades (Piekny & Maehler, 2013). These researchers, with different foci and findings, suggest the complexity of children's reasoning, which clearly represents a challenge for elementary teachers who are tasked with cultivating children's scientific thinking.

In school science classrooms, much of children's reasoning is practiced and understood within individual contexts. That is, each child works on questions and problems presented by teachers and children provided their answers to teachers (Mercer, 2008). To understand the overall abilities of children's reasoning and scientific explanation, children's individual answers are then counted, analyzed, and categorized, which prohibits the understanding of the dynamics of children's reasoning in classroom situations (Macagno & Konstantinidou, 2013). When children's reasoning is taken as individual thinking, isolated from their learning environment or social interactions with other learners, this excludes ideas on learning as social action that develops through an interpersonal level first and intrapersonal level later (Vygotsky, 1978). Thus, in this study, collective reasoning and problem solving are explored in children's learning in science classrooms. *Problem solving* refers to the classroom situation where children encounter a big question or problem context and they attempt to solve puzzling questions and ideas through classroom activities and discussions. Collaborative problem solving has been recognized as an effective interdisciplinary approach to develop students' cognitive reasoning and social knowledge of communication and decision-making skills in science education (Akkerman et al., 2007; Kelson & Distlehorst, 2000; Kim & Tan, 2013; Taconis, Ferguson-Hessler, & Broekkamp, 2001; Tolmie et al., 2010; Zittoun, Baucal, Cornish, & Gillespie, 2007). A dialogical setting to solve problems provides a context where students can make claims, negotiate, and integrate different types and levels of evidence and other knowledge, look for solutions to socially relevant questions, and generate new knowledge into new issues (Hmelo-Silver & Barrows, 2008; Polk & Knutsson, 2008; Ramadier, 2004). In collective problem-solving contexts, children think and learn through interactions with others. This notion of thinking and learning as social action becomes salient in classroom settings when children become engaged in classroom conversations. When children participate in dialogues, often with the teacher, a joint intellectual realm of learning emerges to co-construct new thinking, reasoning, and problem solving. This realm is known as the intermental development zone (IDZ), which Mercer (2008) developed based on Vygotsky's concept of zone of proximal development. In the IDZ, children and teacher dialogue together to solve their common problems based on sociocultural knowledge and ways of thinking. Through the dialogues, children's ideas, inferences, and reasoning skills are shared, responded, and developed. Further, reasoning within collective levels is crucial for critical and creative decision-making and problem solving.

Based on various studies on reasoning and children's scientific thinking, this study argues that children's reasoning as a critical component of scientific literacy requires thinking and explaining through theories and evidence, and reasoning as social activity emerges and develops in and as social relations among learning members in classrooms. Children respond to classroom phenomenon spontaneously and reflectively. Reasoning (reflective thinking) recognizes the latter more—that is, children's reflective thinking and decision-making with/through claims and evidence. This requires children think and explain through their knowledge, experiences, and imagination to seek meanings of the situation at hand, which goes beyond the level of making a simple, intuitive statement on observation (intuitive thinking). Studies that seek to develop children's reasoning skills have often focused on teaching children how to reason in science education. The dominant approach, however, has been individual-oriented, taking reasoning as an individual cognitive process. This approach lacks the understandings of how children develop high-order thinking skills through social relations. Unlike many previous studies on children's reasoning process as individual abilities of thinking, this study emphasizes that reasoning as higher order thinking emerges and develops first through social relations, which are individually internalized later. Classroom interactions, such as the configuration of learning materials, peers, and teachers, challenge and transform children's thinking and reasoning. Based on these ideas, this study is particularly interested in how children's reasoning develops in and through collective dialogues in classrooms when children and teacher attempt to solve their questions together. The specific research questions are as follows:

(1) How do dialogical interactions affect children (Grade 2/3)'s reasoning and explaining?
(2) How do children construct relations between theory and evidence in and through dialogical interactions?

Research: A case study

Research Context

Descriptive and explanatory case study is employed as a research method in this study. The case study is a way to show the context and interactions among participants in a real-life context, which is a science classroom in this study (Baxter & Jack, 2008). Mercer (2008) emphasizes the importance of examining the temporal relationship between the organization of teaching and learning and classroom dialogues in order to understand how learning and teaching develops over time through a series of lessons and activities. That is, a scene of classroom dialogue can show the current phase of children's reasoning and learning in relation to sociocultural contexts of classroom activities and knowledge development over time. This study examines classroom scenes as cases of temporal relationships of children's reasoning and dialogues to their knowledge and skill development throughout the unit learning. Based on observing and analyzing the cases of children's classroom dialogues and interactions, this study questions how children in early elementary grades participate in and develop a collective reasoning process.

The study was conducted in a Grade 2/3 classroom at an elementary school in the western Canada. Eight second graders (7–8 years old; 6 boys, 2 girls) and eight third graders (8–9 years old; 2 boys, 6 girls) worked together in a multi-grade class throughout the school year. The classroom teacher was a dedicated teacher with more than 5 years of teaching in elementary classrooms. She focused on developing children's scientific thinking and interest in science. She was keen to develop an inclusive classroom environment in which children with different backgrounds, interests, and academic abilities worked together to enjoy learning and helping each other. During the research period, children studied an earth science unit about the basic properties of air, water, and soil, which included topics such as air pressure, the stickiness of water, density and buoyancy, water cycle, and types of soil. Throughout the study, the teacher designed lessons with science questions, activities, and classroom discussions. At the beginning of each topic, the teacher provided children with a key science question and then presented follow-up activities that the children could use to solve the given question. Children participated in making predictions and claims, conducting hands-on activities, and sharing their explanations during group and class discussions. During the study, children often participated in group work during science lessons. There were several small groups of four to five children (mixed ages and genders) during the lessons, but those groups were not specifically formed for this study. Sometimes children moved from one group to another based on classroom activities or their personal preference. Children also gathered in the middle of the classroom to participate in class discussions.

Method: Data Collection and Analysis

The data collection was done for five months (mid-January to mid-May 2013) in the second term of the school year. To record children's classroom activities, there were two cameras and two audio recorders set up in the classroom. One camera and voice recorder were recording the whole classroom, and the other camera and voice recorder were set up near a group of four children. The group was chosen based on the level of children's active participation. In the group, there were two girls in Grade 3 (Eva and Noel) and three boys (Kevin, Colin, and Ewan) in Grade 2. These children worked together on classroom tasks, but they also interacted with other groups frequently. That is, sometimes other children came and joined their group conversation since the teacher was not strict about children's grouping. Thus, in the data of group discussion, other children's voices are also analyzed. Twenty science classes were video and audio recorded. Each science lesson was 50–60 minutes long.

The whole data set was clustered into science topics that the teacher designed as curriculum process (air pressure, the stickiness of water, density and buoyancy, water cycle, and types of soil) to understand how concepts and skills develop over time. Each divided section of the data set was examined to understand how children interacted in classroom discussion when they encountered puzzling questions or tasks. During the preliminary data analysis, children's collective discussion did not occur every lesson. The teacher employed various instructional strategies, including lecture, artifact building, science notebook writing, and video materials for children. When these strategies were used, there was not much classroom discussion on the topic. Since the study aimed to examine children's reasoning through dialogues, those lessons where there was not much dialogue were not analyzed for further discussion. For the topics of air pressure, water cycle, and types of soil, there were more lessons with the teacher's lecture, hands-on activities and writing, making artifacts, and watching video materials and less of children's discussion. There was no significant amount of dialogue among the children and the teacher to solve problems throughout the lessons. Thus, after the preliminary video analysis, two topics (four lessons about the stickiness of water and five lessons about floatability in the unit on density and buoyancy) were chosen for further data analysis because these two topics contained big questions and problems, which were assigned by the teacher or emerged from class discussion. Therefore, much conversation and interactions among children and teacher were observed. There were four video clips on the stickiness of water and five video clips on density and buoyancy. Once the topics were chosen, a colleague in science education was invited to data-sharing sessions and analysis for peer checking. There was some degree of disagreement on coding schemes and argumentation development during the initial interpretation, such as whether claims were developed or repeated as part of code checking (Miles & Huberman, 1994). This was solved by intensive discussion and revision through interactive video analysis approach (Jordan & Henderson, 1995). Interactive video analysis requires that peers view and interpret video clips together by critically and creatively examining each other's interpretations and themes in order to reach an agreeable data analysis. During the interactive analysis, interpretation, themes, and codes were discussed. For the depth of data analysis, a two-space model of the whole-class discussion was also adapted (Eshach, 2010). In this model, Eshach (2010) explains that the whole-class discussion could be divided into individual and collective space. Individual students are processing their personal ideas, which are influenced by conceptual barriers. Their ideas are shared and processed in collective space with peers and the teacher's interventions. The interactive activities in the collective space coalesce as conceptual flow patterns. Even if children's reasoning and ideas cannot be fully personal or individual in classroom situations because their thinking and ideas develop with/as collectivity (Roth, 2013), analyzing individual ideas within dialogue is still valuable to understand children's reasoning in and through the whole-class discussion. Thus, this study focuses on conceptual reasoning flow in individual and collective space by mapping classroom dialogues. To do so, this study followed these steps of data analysis:

(1) stating the big problem/puzzling question (problem-stating),
(2) children's individual ideas (claim making),
(3) interactions among those ideas (accepting/supporting/rejecting claims, evidence evaluation, etc.), and
(4) concept/idea development and solution.

Video files (mp4) of classroom activities and group discussion were reviewed several times and transcribed for data description and analysis. Review of the videos focused how problem tasks and puzzling questions emerged, how children responded, and how children themselves and with the teacher interacted to solve the problems. To code children's class conversation, coding schemes were developed during the initial review of data. The coding schemes are *puzzling question emerged* (if a question/problem is emergent); *claim/counterclaim made* (if a child proposes any claim to the question); *claim repeated, rejected, or supported with and without evidence* (how a child responds to a suggested claim with or without evidence); *claim developed and finalized* (if a child develops a suggested claim toward expected knowledge of concepts); *teacher intervention* (if the teacher proposes something to develop class dialogues and reasoning); and *solution* (if a child suggests a solution/answer to the problem/question) (see Dialogue #1 and #2). These coding schemes were useful to determine whether children presented claims with evidence and how the teacher intervened in children's dialogues to promote reasoning. The codes did not, however, measure the collectivity and interactions of children's reasoning—that is, how children interacted each other to develop their ideas and evidence and reached conclusions together. To see the interactions of ideas among children, reasoning mapping was adapted from Hoffmann and Borenstein's (2014) work on argumentation mapping. The mapping strategy was useful to understand how children's claims and evidence were connected and developed throughout classroom dialogues. In this paper, case analyses of children's interactions on the 'stickiness of water' and 'floatability' will be introduced and discussed since these two topics provided robust episodes of children's collective reasoning through their classroom dialogues.

Findings

Children's Reasoning as Collective Action

Children in science classes often encounter abstract and unfamiliar questions. For instance, when children observe dissolving sugar in water, the teacher asked the children, 'Will sugar dissolve faster in warm or cold water?' or 'Why does sugar dissolve faster in warm water than cold water?' The former question can be solved by conducting an experiment and answered based on the observable evidence. However, when they attempt to explain why sugar dissolves faster in warm water, the question challenges children to reflect on their observation, knowledge, experience, and imagination. This type of why question is frequently asked in science classrooms to encourage children to get engaged in and develop reflective inference or reasoning (Mercier, 2011). During children's classroom discussion in this study, children made intuitive inferences and claims. When they were asked to explain differences and cause–effect relations beyond their claims, children had to reason further with prior knowledge and experiences, which requires the process of reflective inference and evaluation. When children attempt to think through and answer the question by connecting their prior knowledge with experience, new imagination, theory, and knowledge emerge through their reasoning process. How do they make these connections of knowledge and experience as a social collective? Is collective reasoning an effective process to develop a new theory or explanation in science? The analysis of classroom data in this study focuses on the interplay of claim, evidence, and evaluation in children's classroom discussion. The following episode (Case #1) demonstrates how children reason at a collective level and how collective dialogue develops their ability to reasoning and construct knowledge.

Case #1: sticky water

The teacher and children studied the concept that water has surface adhesion. In one activity, the teacher used a demonstration to motivate and teach children that water molecules stick together (see Figure 1 for the process of the activity). The teacher prepared two sets (A and B) of demonstrations with two sets of four identical jars of water and a tube. She connected two pair of jars with the tube. In Set A there was water in the tube, and in Set B there was no water in the tube. She asked the children to identify the difference between Set A and B; the children noticed that there was no water in the tube in Set B. She confirmed this by showing the tube to the children (Figure 1(a)). She lowered one jar down to the floor in Set A (Figure 1(b)), and water started moving down from the upper jar to the lower one (Figure 1(c)). The level of water in two jars in Set A was observable (Figure 1(d)). She repeated this a few times and started the process with the Set B and there was no water movement between the two jars (Figure 1(e)).

The following dialogue took place when she lowered one jar in Set B and asked children what they observed.

Dialogue #1

1–1	Teacher: Now putting it down … Watch! Is it rushing in?	*Puzzling question emerging*
1–2	John: Slowly happening.	*Claim made*
1–3	Teacher: Is it?	*Teacher intervention*
1–4	Children: No, no.	*Claim rejected*
1–5	Teacher: I don't know. I don't see anything happening.	*Claim made*
1–6	Children: No. Not in the tube.	*Claim supported*
1–7	A girl: Only atoms … (inaudible)	*New claim made*
1–8	Kevin: Only atoms are going up to the tube and it startsscrolling and it goes ouhhh and back into the cup …	*Claim supported*
1–9	Teacher: It's not changing.	
1–10	Kevin: The atoms are moving though.	*Teacher intervention*
1–11	Teacher: Inside the jar, but are they moving from onejar to the other?	*Claim repeated*
1–12	Children: Nope.	*Teacher intervention*
1–13	Teacher: What's going on? Why was there water downwhen the tube was full of water and the other is not?	*Teacher intervention*

In the dialogue, the teacher asks the children if the water was moving from one jar to the other. John answers that water was slowly moving to the jar (turn 1–2) but other children answered nothing happened (turn 1–4). John's claim was rejected by others based on their observation. The teacher also shared her observation that she did not *see* anything happening in the jar. The children confirmed that there was no visible change happening in the tube. Then a girl came up with the idea of atoms that might be moving (turn 1–7). Kevin elaborated on the idea of atoms further (turn 1–8). In the previous class, children learned atoms and molecules were invisible and moving around in the water from the activity of having a tea bag

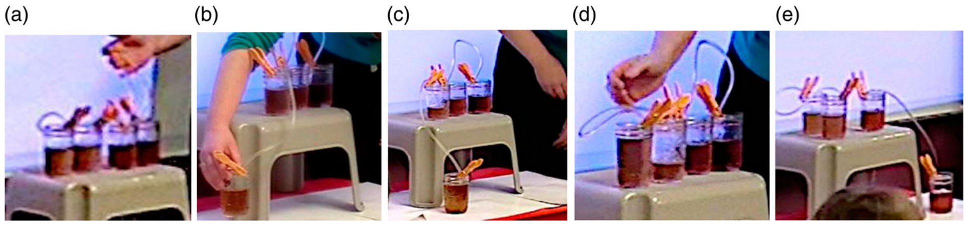

Figure 1. The teacher's demonstration on sticky water.

steep in a water jar. In this dialogue, the children were trying to explain what was happening in the jar by connecting their observation of the demonstration, knowledge about atoms from previous classes, and imagination. The idea of invisible atoms became one explanation or hypothesis of the phenomenon they were observing. Researchers know that children's observation and explanation are often affected by what they expect to observe and what they believe (Eberbach & Crowley, 2008). Children are often selective and adjust what they observe to fit to their own beliefs and favored outcomes (Kuhn, 1989). This might suggest that John expected to see water moving into the other jar and made his explanation accordingly. Other children connected their knowledge of invisible atoms to John's explanation that something has to move (turn 1–7, 8, and 10). Kevin explained, 'Only atoms are going up to the tube and it starts scrolling and it goes ouhhh and back into the cup.' The teacher shared the evidence that the water level did not change. Kevin insisted on his idea, stating that 'the atoms are moving *though*'. Then the teacher reoriented the question by emphasizing water movement from one jar to the other. The children needed to look for another claim to explain the situation. The class questions were shifting from 'what is happening?' to 'why do they think that's (not) happening?' by the teacher's turn taking (turn 1–13).

To the question on the causal relationship of water transportation, children continuously attempted to connect their prior knowledge to the unknown situation. In the following dialogue, children question what the water in the tube was doing to create different notions in the two demonstration sets. Colin made a claim that seemed to orient children's thinking toward another direction. Colin explained that the water in the tube was pulling water from one jar to the other (turn 2–1, 2–3).

Dialogue #2

2–1	Colin: So I think when you put the water down here,it is pulling one of it.	*Claim made*
2–2	Teacher: So you can get the water from here …	*Teacher intervention*
2–3	Colin: No, no. I am saying the water pulling in thisone down the hill and the water in that tube pushingthis water down and then that water up.	*Claim continued*
2–4	Teacher: So do you think the water on the tube is pulling the water down?	*Teacher intervention*
2–5	Colin: Ya!	*Claim supported*
2–6	Teacher: You guys, think about that.	*Teacher intervention*
2–7	Others: Yah, yah!!!	*Claim supported*
2–8	Teacher: You, think about that.	
2–9	Ewan: I think that is too. (John is raising and waiving his hand enthusiastically.)	*Claim supported*
2–10	Teacher: What is pulling the water down to the bottom? Why does the water want to go down the hill? You guys are very smart …	*Teacher intervention*
2–11	John: I remember when we were putting the dropsof water on wax paper, they always wanted to stick together.	*Claim supported with evidence*
2–12	Teacher: Oh!	
2–13	John: I think that's coming just in the tube.	*Claim developed*
2–14	Teacher: So you think that's what's happening? So youfound out the water molecules really what?	*Teacher intervention*

2–15	John: Stick together.	*Claim made*
2–16	Teacher: So …	
2–17	Eva: So, that's why, it isn't sticking together 'cause there is no water in that tube.	*Claim developed*
2–18	Teacher: There're no water molecules in the tube. So …	*Teacher intervention*
2–19	Eva: So, there needs to be water in the tube so that theycome and stick together.	*Claim finalized/solution*

Colin brought up the idea that the water in the tube was pulling the other water down to the jar (turn 2–1, 2–3) and teacher encouraged Colin to elaborate his ideas further (turn 2–2, 2–4). The teacher positively urged children to consider Colin's idea. The idea seemed convincing to the other children. The children showed their acceptance on the idea by saying 'yah, yah' (turn 2–7) and Ewan added, 'I think so too' (turn 2–9). As Ewan spoke, John enthusiastically started to wave his hand, wanting to speak. He continued waving his arm until the teacher gave him a chance to speak. Then John shared what he remembered from the previous class on wax paper and made the connection between the water on wax paper and the water in the tube. Then he finished the sentence that teacher started. The water molecules (by the teacher, turn 2–14) stick together (by John, turn 2–15). This invited Eva to participate in the dialogue. She explained, 'So that's why it isn't sticking together 'cause there is no water in that tube.' Throughout the process of dialogue, the children, with the teacher's guidance, actively supported, changed, and developed ideas to explain why water moved in one set and not the other. The children's problem solving was a collective reasoning process. The idea of the stickiness of water that pulls water from one jar to the other was emerging through the participants' speaking, responding, remembering, connecting, and evaluating the group's ideas. The emergence of knowledge was possible only through the interplay of these dialogical interactions and reasoning between children and the teacher.

In the mapping, individual's claims are confronted, supported, and/or rejected in collective space (Figure 2). Throughout the interactions, children's reasoning on why water was moving in Set A, not B was progressed and developed based on each other's claims, evidence, and interaction. To reach the conclusion to the puzzling question (there needs water in the tube in order for water to move from one to the other jar), children reasoned together, connecting each other's ideas.

Evaluating Evidence, Collective Knowledge, and Consensus Building

Children's beliefs, the goals of tasks, and norms/expectations in classroom environments can influence their decision-making and problem solving when they encounter contradictory or opposing ideas (Berland & Lee, 2012). Case #2 below illustrates how consensus around collective knowledge is built and becomes a basis of problem solving when children encounter conflicting ideas. The episodes and dialogues below present how different ideas are confronted and how children solve the contradiction and reach a certain conclusion through their dialogues.

Case #2: floating carrots in salty water

In previous classes, children observed pieces of carrot floating when they dissolved salt in the water. The children attempted to explain what happened to salt and carrots by making two claims: (1) salt was soaked into carrots and (2) carrots got heavier. But soon they found these two ideas contradictory to their knowledge on floatability—namely,

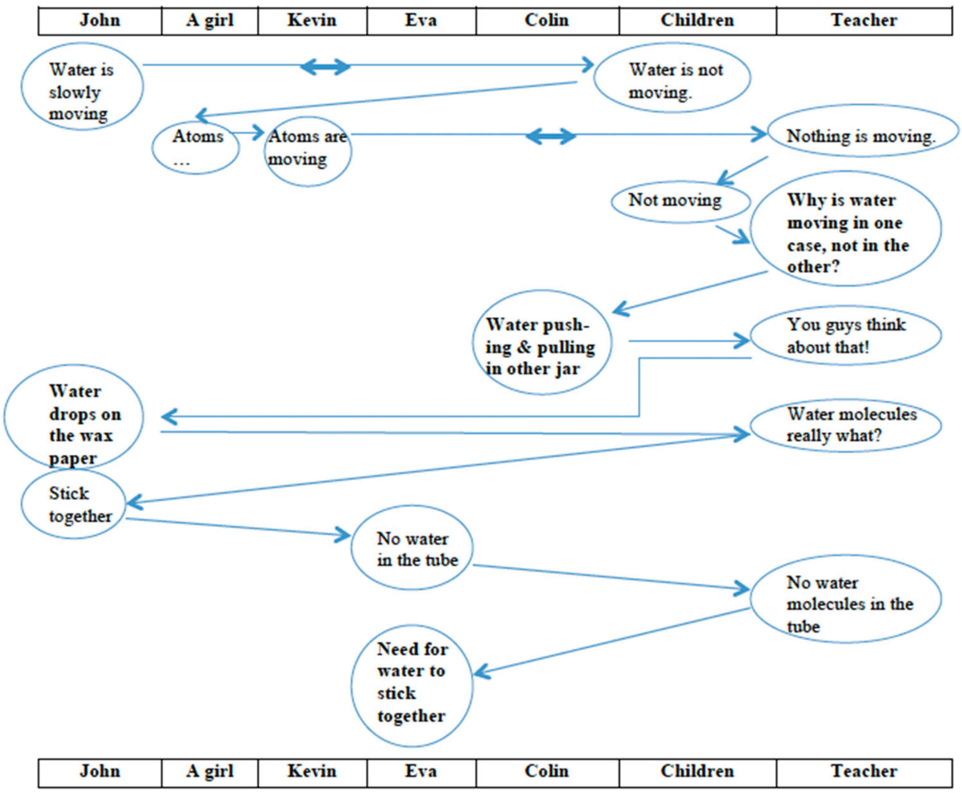

Figure 2. Reasoning map on why water moves/does not move.

'heavier means sinking'. If carrots soaked salt, they should get heavier and thus sink, not float. The claim, observation, and knowledge on floatability were not aligned and were contradictory for children. Attempting to resolve this contradiction, Ewan shared his first-hand experience that he observed rocks floating in a water tank (turn 3–1). He said that *getting heavier* could make carrots *float*. However, this did not seem convincing to his peers. The other children, including Noel (turn 3–2) and Olive (turn 3–3), rejected Ewan's explanation.

Dialogue #3–1

3–1	Ewan: I have different ideas, I saw this in WillowTown [local aquarium], at a … somewhere in Willow Town, 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.	*Claim made*
3–2	Noel: That makes it sink.	*Claim rejected & counter claim made*
	…	
3–3	Olive: But, the lighter ones should float and the bigger ones should sink.	
3–4	Noel: Because littler rocks are lighter than great, bigger rocks.	*Counterclaim supported*

In the dialogue, Noel and Olive hypothesized that heavier objects sink and lighter ones float. Ewan's idea was rejected by their beliefs. The dialogue was developed further by Kevin's idea. Kevin also saw the rock in the aquarium but found out the rock was plastic, not actual rock. It was lighter than actual rock.

Dialogue #3–2

3–5	Kevin: I know why Ewan 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. …	*Claim Supported/developed*
3–6	Kevin: Ya, because plastics are actually lighter than actual rocks.	*Claim supported with evidence*
3–7	Teacher: Oh. so it looks like big heavy rock, it's sitting in themiddle (Kevin: ya) and it floats when you add water, and theother things sink to the bottom even though they look smaller,	*Teacher intervention*
3–8	Kevin: Ya, because plastics are actually lighter than actual rocks.	*Claim supported/ developed*
3–9	Teacher: but I like how you are using evidence, because you saidyou 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.	*Teacher intervention*
3–10	Ellis: Yap!	

After Kevin's evidence sharing, children and the teacher discussed why Ewan's claim was confusing and needed to be rethought. Kevin's sharing during the conversation provided a missing piece of evidence to explain why the rock-looking object was floating and alleviated the conflicts among claims, evidence, and knowledge. The idea that heavier objects sink was becoming children's accepted knowledge. In this episode, it was evident that children's reasoning was collectively shared and developed to construct a claim they would agree upon and the teacher was participating to assure the role of evidence in children's reasoning and decision-making. Throughout the dialogues, the children's evidence was actively evaluated by their knowledge of weight, experiences of weighing, and an object's floatability. Ewan's observation of rocks floating in the water helped him reason that carrots soaked up the salt (accepting the suggested claim) and, thus, they got heavier and floated (proposing his new claim). His experience at the aquarium provided him an evidence to think about possibility that carrots with more weight could float. In an individual unit of Ewan's reasoning, the relation between theory and evidence seems plausible and rational. The evidence that heavier rocks floated and smaller ones sank was backing up his claim that carrots got heavier, thus floated. However, his reasoning process was challenged by other children who believed that getting heavier makes objects sink. This conflicting moment was resolved by Kevin. When Kevin shared his experience, the idea of 'heavier means sinking' became salient, confirmed, and accepted by children. It became a collective knowledge among children. The children's ability to evaluate evidence and resolve contradictory ideas were developed based on their beliefs, knowledge, and experiences. In addition, through the process of evidence evaluation, a collective knowledge and consensus around the knowledge they were exploring was emerging—that is, that heavy objects sink. Smith, Carey, and Wiser (1985) found that children around 5–7 years old held the concept of weight as felt weight and could not distinguish the concept of weight from density, whereas older children, around 8 or 9 years old, started to articulate those concepts distinctively. In this study, children made claims on weight and density with intuitive inference such as *rocks are heavy thus cannot float*, and they encountered the next puzzle—

why it floated. Children collectively and with the teacher challenged those puzzles by questioning and testing evidence and experiences to reach a conclusion that they could agree upon. By situating themselves in collective bases of problems and claims, the children move towards seeking ways of solving different problems. When a claim is collectively accepted, there is a possibility that consensus can be established on that particular claim. Then, the members tend to evaluate new evidence and evidence based on the consensus, or ignore counterclaims. In this regard, children's collective knowledge and consensus could also contribute to the emergence of confirmation bias in group argumentation (Berland & Lee, 2012; Kuhn, 1991). The following episode illustrates how collective knowledge and consensus might form a critical aspect of children's problem solving but also play as confirmation bias to ignore counterargument in their decision-making.

Based on their collective knowledge, 'heavier objects sink', the children were confronted with the idea that salt did not make carrots heavier. In their claim-making process, the collective knowledge that (1) salt was soaked and made carrots float → (2) heavy objects sink and → (3) thus, salt must have made carrots *lighter* began emerging, and a consensus was built up around the new knowledge. Based on this accepted knowledge, the children questioned how salt made carrots lighter and how they might test that carrots got lighter. When the teacher asked how they could know carrots got lighter even though they did not seem getting smaller in salty water, Colin excitingly answered, 'oh oh oh, maybe the salt is soaked into the middle and eating away the carrots from the inside out and we couldn't see it'. This claim seemed to be accepted by the children because they could not see any changes on the surface of the carrots and the children wanted to find a way to prove that the middle part of the carrots were dissolved. Then, Ewan raised a counterargument. Ewan reminded them of the video clip on people floating on the Dead Sea that they watched in the previous class (turn 4–1). However, Ewan's counterclaim was rejected.

Dialogue #4

4–1	Ewan: I am not chasing that it, err, the salt eating out the middleof carrots that we didn't see what is on part of it because,then how would be humans float better in salty water?(John: Ya, that probably.) How could it be eating on the inside?	*Claim rejected with evidence*
4–2	John: (quiet sound in the background) Maybe that'sclothes on or skin …	*Claim supported with evidence*
4–3	Teacher: That's really good evidence. Right?	*Teacher intervention*
4–4	Colin: … (inaudible) Maybe because humans are harderinside than carrots are. So that's why.	*Claim supported with evidence*
4–5	Kevin: We have bones.	
4–6	John: Because part of carrots is showing inside, but us,part of us is not showing because of skin	*Claim and evidence repeated*
4–7	Kevin: Because we are in skin, we are in bones,and what we are in … A girl: … (inaudible) stuff	*Claim developed*
4–8	Kevin: Ya!	
4–9 4–10	Teacher: Ok, we are protected by skin, it doesn't appear that human's getting dissolved by the salty water, however, human did float better in the salty water, so we have to figure out why. It seems to work on humans and carrots and do you think the reason is different from humans than it is for carrots?	*Teacher intervention*
4–11	Eva: Yes!	

Ewan reflected on the video clip of people floating on the Dead Sea (turn 4–1). This moment could have been an opportunity for the children to reject Colin's claim by evaluating the evidence suggested by Ewan and the teacher assured them that it was good evidence (turn 4–3). However, the children, including John and Kevin, supported Colin's claim by suggesting that humans have other structures (skin, bones, clothes, etc.) on their bodies, which may be different from carrots (turn 4–2, 4–5 to 4–11). The teacher summed up what children had explained but also raised question on why the two cases were different (turn 4–10). Even though the children watched the video clip together and were amazed by people floating and reading books in the sea, Ewan's suggestion was ignored by the idea that human and carrots are different in structure and hardness. It seems that once a claim and knowledge is accepted on a collective level, it is hard to break the level of trust. The accepted claim became absolute knowledge, which forms the basis of future problem solving. The children agreed that carrots soaked in salt got lighter (because they floated). Based on this dialogue, Colin's hypothesis on how carrots might become hollow inside seemed convincing to other children. Based on agreed knowledge through the collective reasoning process, the children seemed to support Colin's claim and rejected Ewan's counterclaim that might undermine their accepted knowledge. After the Dialogue #4, the teacher asked how children could test their hypothesized claims such as

> how would we be able to test that to know in fact that part of the carrots of the carrots is disappearing from the beginning of the experiment to the end of the experiment? How would we be able to test to know in fact that's what is really happening?

With her attempts to question how to test and how to get evidence, the children came up with two ways to test their claims: (1) cutting carrots in half and (2) weighing carrots on a scale before and after salty water. Children were divided into two groups. One group cut carrots in half after they poured salt in the water and saw carrots floating. When they cut the carrots, they did not find any signs of melting or reduced part inside the carrots. The other group weighed carrots before they poured salt in the water and weighed them again after the carrots started floating. There was no weight change. They concluded that their hypothesized claims were not correct. Later on, the children participated in other activities to develop their concept of density in fresh and salty water. Figure 3, a reasoning map of why carrots float, shows that individual claims are supported and rejected dynamically based on evidence, experience, and prior knowledge in collective space. In other words, children's reasoning and ideas develop collectively in a shared space, which could never be possible in individual realm.

Discussion

This study explored and analyzed the two episodes of children's dialogues in science classrooms. These episodes contain rich dialogue that contributed significantly to the study's broader data set. In short, these two episodes provide useful and viable understandings of how children reason and develop ideas in collective space. Based on the findings and analysis of Case #1 and #2, three educational implications arise: (1) children's reasoning and problem solving is collective and dialogical; (2) the emergence of collective knowledge and consensus is a driving force of problem solving and yet could form a bias to limit exploration on counterclaims and evidence; and (3) scaffolding is challenging in children's collective reasoning and problem-solving process.

Reasoning as Collective Process

In problem-solving activities, children learn to reach desirable solutions or outcomes through acquiring, communicating, and integrating knowledge and skills (Duch, Groh, & Allen, 2001). During collective reasoning and problem solving, children's learning is prompted, motivated, and developed by others' actions, and new knowledge emerges in the collective realm (Johnson, Johnson, & Smith, 2007; Lee & Duek, 2000; Scardamalia, 2002; Wells, 2002; Zhang, Scardamalia, Reeve, & Messina, 2009). Thus, it is considered as an effective approach to develop children's cognitive and social reasoning process (Akkerman et al., 2007; Kelson & Distlehorst, 2000; Tolmie et al., 2010; Zittoun et al., 2007). The episodes shown in the findings above explain how children's reasoning was processed and developed through dialogical problem solving in classrooms. Children's reasoning was a collective action of evaluating evidence against or for their existing and emerging theories. Through collective dialogue, the children showed their skills at making claims and counterclaims and evaluating the evidence. The children actively supported and rejected each other's claims and evidence based on their own experiences and knowledge by making connections between what they know (theory) and what they experience (evidence) and further to what needs to be proven in classroom situations. They could make a causal-relational reasoning on the carrots, salt, and floatability to design tests to investigate their hypothesis. For instance, John could make the connection between the observed notions in the classroom (evidence) and stickiness of water (theory) through interactions with other children in Case #1. When Colin suggested that the water in the tube was pulling itself down, John attempted to explain his observation of water on the wax paper from the previous class. The connection between water in the tube and water drops on wax paper was made possible through their explanation about the current problem of why water moves in one set and not the other. Their explanation

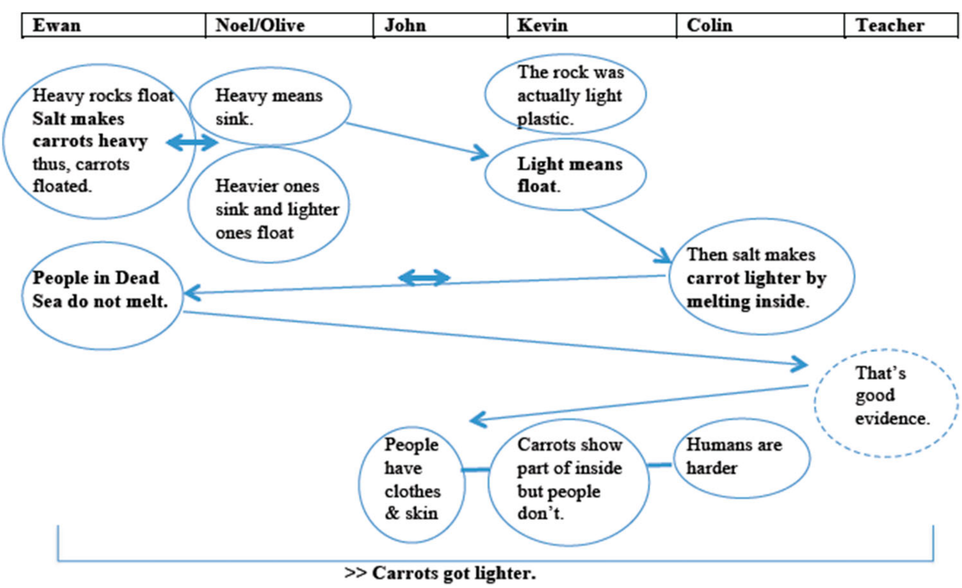

Figure 3. Reasoning map on why carrots float.

could only emerge through the interactive conversation that further developed the children's reasoning through the connection of evidence and knowledge.

This collective and interactive reasoning process was also noticed in Case #2. Ewan's evidence about the floating rocks was challenged by other children's theories (knowledge and beliefs) in the discussion. Colin's claim that salt is eating up carrots was challenged by Ewan's counterclaim and evidence of the people floating in the Dead Sea. Other children supported Colin's idea about the physical differences in structures between the human body and carrots. The children actively evaluated the evidence and explained their justification of their claims by making connections between what they know and what they observed. With the challenge and support from each other, the children reached a certain conclusion as a collective to move forward with their problem solving. The dynamics of evaluating and justifying children's theories and evidences were complex and unpredictable with many diverse ideas and active interactions. The process of reasoning was a social activity—that is, *participative, collective, and logical*. It was not individual action (Goulart & Roth, 2009). Given that learning is not only a cognitive action but also a social process (Mercer, 2008; Nielsen, Du, & Kolmos, 2010; Wells, 2002), it is critical to encourage children to become engaged in thinking and reasoning collectively through dialogical development in classroom contexts (Psaltis, Duveen, & Perret-Clermont, 2009).

Collective Knowledge and Consensus

Children's reasoning in the social realm supports collective knowledge building and advancement (Hmelo-Silver & Barrows, 2008). In collective decision-making and problem-solving process, the children are challenged when their collective ideas and knowledge are contradicted by counterclaims or evidences, which thus requires them to reexamine or change their claims. This process is also known as *peer legitimatization* (Berland & Lee, 2012). Previous research has shown that peer legitimization is influenced by the strength of children's beliefs, their goals or expectation for interactions, and their attitudes toward opposing views from peers. The case of the floatability of carrots illustrated how collective knowledge emerged and built a collective consensus through peer legitimatization, which then formed the foundation of solution seeking. Throughout the children's conversation, the idea of heavier objects sinking became a salient and critical basis to determine the direction of problem solving. For instance, in Case #2, the children developed the claim that 'carrots got lighter, instead of heavier' based on their collective agreement (knowledge and belief) of 'heavier ones sink and lighter ones float'. Based on this agreed idea, another claim—'the middle part of the carrots was eaten up by salt'—was created. This claim got legitimized based on their collective consensus that 'heavier means sinking', and the built consensus provided a momentum to children to process their hypothesis and testing strategies.

Yet the episode also suggests that the notion of consensus building could influence children's evaluation of evidence in a limited way. Based on the grounds of their collective knowledge and consensus, children seemed to ignore Ewan's counterclaims and evidence.[1] They could revisit and revise their claim. However, they kept their agreed ideas by refuting Ewan's evidence. Previous research on the coordination between theories (explanation, knowledge, or beliefs established by children) and evidence (observed phenomena or data) in children's reasoning illuminate complex notions of children's abilities for reasoning and argumentation. That is, some researchers explain that children's reasoning and decision-making might involve consistency with background beliefs or prior knowledge more often than evidences (Croker & Buchanan, 2011; Koslowski & Masnick, 2011; Kuhn & Pearsall, 2000). Children's evaluation of evidence also tends to be based upon their beliefs and knowledge when they are not giving enough attention to new evidences. Kuhn (1989) explained that young children's argumentation is belief-based rather than evidence based. When children observe a phenomenon or test a hypothesis that confounds their prior beliefs or knowledge, they tend to ignore discrepant evidence or attend to it selectively. Thus, their causal reasoning and processing on the reliability of data becomes interrupted. Ewan's firsthand experience of observing a heavy rock floating was rejected based on other children's beliefs on floatability. Kevin's counterevidence about the plastic rock strengthened the group's beliefs and developed a collective consensus around the beliefs. Based on the beliefs and consensus, the children agreed that salt dissolved carrots. This collective consensus was strong enough to reject Ewan's evidence about the floatability of people on the Dead Sea. As other research has shown, children at this age level demonstrated a belief-based reasoning process, and this notion appeared within a collective realm in this study. These examples illustrate how the emergence of collective knowledge and consensus becomes a basis of problem solving and how they might influence children's evaluation and justification of claims and evidences. This leads to the pedagogical challenge of developing children's reasoning collectively in classrooms, which is discussed in the following section.

Challenges of teaching and developing collective reasoning

The process of children's collective reasoning and problem solving is complex and nonlinear, which causes some tension in teacher's scaffolding and decision-making about how to orient children's conversations. Given that the teacher is a member of the classroom collective, this study raises important questions about how the teacher participates in classroom discussions and how he or she might scaffold children's reasoning and problem solving. How do teachers immerse themselves in the collective dialogue and scaffold the conversation to develop children's critical thinking and reasoning? What pedagogical strategies might teachers use when children are building consensus around popular but inaccurate beliefs that might hinder their evidence evaluation?

The teacher in this study played the role of participant in classroom conversation to share ideas and evaluate evidence together with children. When children encountered challenges of evidence evaluation or problem solving, she did not give out answers to students. Instead, she attempted to develop children's reasoning and problem-solving skills by raising questions and inviting children's ideas and encouraging them to interact with each other to solve problems. As illustrated, the teacher could neither predict what was coming next in children's conversation nor lead their conversation over consensus building and evidence evaluation. When the other children rejected Ewan's evidence, she as a teacher encountered a certain level of pedagogical tension. She did not explicitly say that the counterevidence was correct and thus their claim was wrong. Instead, she attempted to scaffold the discussion by encouraging the other children to reexamine their claim; she said, 'that's [Ewan's point] really good evidence. Right?' However, her comment was not able to lead children to reexamine or revise their claim. It was a critical moment for her to decide whether she let them go with their own justification or redirect their conversation to revise their claim by explaining or raising more questions. She chose to let children explore their own ideas and test them out. This non-linear nature of children's dialogues and problem solving challenged the teacher, presenting her with the problem of scaffolding for the autonomy of collective reasoning and desired knowledge in science learning.

By using collective reasoning and problem solving as a way of developing critical minds and creativity in scientific literacy, the teacher acknowledged and built upon the process of children's dialogical interactions mindfully. It was evident that the teacher's scaffolding aimed to generate children's peer interactions to enhance their ideas, questions, and solutions. Roth and Radford (2010) suggest that the notion of scaffolding in zone of proximal development needs to be rethought in classroom learning. Scaffolding is not only that a higher group leads/guides a lower group but the two groups with similar cognitive levels also guide/lead each other by sharing and interacting with different ideas. Rather than understanding the teacher as the expert who scaffolds children as learners with higher knowledge and skills, both the children and the teacher and the children themselves are co-constructing intersubjective feedback which constitutes learning for both the teacher and the children. The children's unexpected responses provide teachers with opportunities for learning about the nature of children's reasoning in problem solving contexts as children construct new knowledge from peer dialogues and teacher's scaffolding in classroom and group discussions. This dynamic interplay of teacher-children conversation is a scaffolding force in the zone of proximal development, where children's reasoning and teacher's pedagogical reflection grow together. Roth and Radford (2010) state, 'the emerging intersubjective attunement is certainly beyond a *pure* cognitive realm' (p. 305, emphasis original). It is the emergence of collectivity that scaffolds children's learning. Mercer et al. (2004) also found that the development of children's scientific understanding and reasoning was best when assisted by a careful combination of peer group interaction and thoughtfully examined guidance from the teacher. Teachers who desire to develop children's reasoning and problem-solving skills through dialogical and collective realms will need to be attentive to the balance between peer and teacher scaffolding and the potential dilemma of desired knowledge and process in children's collective actions.

Closing Remarks: Limitation and Further Study

This study proposed that children's reasoning is a social collective action that allows them to solve science questions and problems through dialogical interactions. Rather than approaching children's reasoning skills with test design or an individual focus, this study looked into an ordinary science classroom where teacher and children discussed their science topics, questions, and ideas as a collective. The cases in this study demonstrated that children in Grade 2/3 actively participated in inferring, collecting, and evaluating evidence and reached conclusions in their problem solving. Yet there are some areas that this study does not explain. This study does not explain how intuitive and reflective thinking types interacts during children's dialogues and how children identify the weakness of intuitive thinking in claim making and explanation in science. Also, this study does not explain how the dynamics of social relationships among children might influence children's evaluation of claims and evidence. These questions are critical to theorizing and developing children's reasoning as collective social action, thus, require further research.

Disclosure Statement

No potential conflict of interest was reported by the author.

Note

1. Beside these grounds, sociological characteristics of this peer group could be a factor of their decision-making, however, there was no particular friendship detected during the project. Also, Ewan's other ideas got supported and Colin's other ideas were rejected by the same children from time to time. Thus, it is hard to argue that the sociological characteristics could determine their decision-making. And yet, it could still be possible in a hidden realm and it is beyond the scope of this project.

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