Emergence of Argumentation in Elementary Students' Science Learning

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Abstract: In the field of science education, argumentation has been supported as a core practice for scientific literacy. Although studies on student argumentation have exploded in recent years, research on argumentation as an emergent phenomenon in school science education has been very limited. This paper aims to explore whether and how elementary students' argumentation spontaneously emerges in the science classroom setting without pre-designed argument-focused interventions. A qualitative case study was conducted in a fifth-/sixth-grade science classroom in Canada over a 4-month period. Data were collected with multiple methods, including observation and interviews. Qualitative data analysis revealed student argumentation often occurred spontaneously in their collaborative problem-solving, when they 1) questioned the rationales of each other's ideas and 2) attempted to reach consensus on their group problem-solving. It was also found that students' appreciation of their collaboration and teachers' scaffolding in problem-solving contexts positively influenced scientific argumentation to emerge and develop.

Keywords: Spontaneous Emergence of Argumentation, Elementary Science, Collaborative Problem-Solving

Introduction

In science education, many researchers agree that argumentation has the potential to enhance students' scientific and critical thinking and promote their scientific literacy, which is widely accepted as the goal of science education (Erduran, Simon, & Osborne, 2004; Kim & Roth, 2014; Sampson & Clark, 2008). Studies on argumentation in the field of science education tend to explore student argumentation by providing pre-designed argumentation tasks, which are usually designed in accordance with their research purposes and with the particular aim to engage students in argumentative practice (Larrain, Freire, & Howe, 2014). This is not surprising given that some scholars explain argumentation is seldom discerned in classroom situations without designed learning tasks with certain structures of argumentation, such as grouping students to debate with evidence on contradictory issues (Abi-El-Mona & Abi-El-Khalick, 2010; Larrain et al., 2014). As a consequence, researchers tend to design learning tasks that could generate either two contrary opinions (Kuhn, Zillmer, Crowell & Zavala,2013) or multiple controversial views (Berland, 2011; Dawson & Venville, 2013) to engage students in argumentation, and then examine students' structured science talks and writing on conflicting ideas as the products of argumentation. Thereby, there is very limited information on student argumentation in classroom contexts without particularly pre-designed argument-focused tasks. Exploring whether and how argumentation would spontaneously take place without particular argument-focused interventions is important. It contributes in facilitating student science learning through integrating argumentation and further supporting argumentation in common or routine classroom practices (Larrain et al., 2014). These practices include students' problem-based learning, which is well-justified and supported as a pedagogical approach thus widely employed in current classrooms (Jin & Kim, 2018). Moreover, in current literature, fewer studies on argumentation have focused on learners at the elementary level compared with learners at the secondary or higher levels.

Given these gaps in the literature, this study aims to explore elementary students' spontaneous argumentative practice in science classrooms, and further investigate possible aspects that impact the emergence and development of argumentation. This study addresses the following questions:

1. How does student argumentation spontaneously emerge in elementary science classrooms?
2. What are the possible aspects that influence the spontaneous emergence of student argumentation?

Argumentation and Argument

This study distinguished between *argument* and *argumentation*, since we attempted to distinguish the artefact produced from the process that produces it (Ryu & Sandoval, 2012). Argument in this study refers to the artefact resulting from an interactional process that we call argumentation. Thus, in a classroom setting, an argument can be any spoken or written text that involves one or more claims and evidence and/or reasoning for or against the claim(s), and argumentation is the process by which such texts are produced, critiqued, or refined (Sampson & Clark, 2008).

Toulmin's (1958) argument pattern (TAP) is widely employed by research on argumentation in science education (Chen, Hand, & Park, 2016; McNeill, 2011) as the framework to interpret students' arguments and argumentation. However, researchers have explained the difficulties of distinguishing structural components of TAP (data, claim, warrants, qualifiers, rebuttal, and backing) in data analysis (Kim & Roth, 2014; Sampson & Clark, 2008). In this study, we adopted a TAP-inspired framework of claim-evidence-reasoning, which has been proven as suitable and effective to interpret elementary students' argumentative practice (McNeill, 2011; Sampson & Clark, 2008). In this claim-evidence-reasoning structure, *claim* refers to a tentative statement or assertion that provides an answer to a certain question or a solution (McNeill, 2011); *evidence*, in its broadest sense, includes anything such as measurement or observation that is used to support or reject the validity of the claim (Sampson & Clark, 2009); *reasoning* refers to the explanation of how the evidence supports or rebuts the claim. Research has shown that students, especially younger learners such as elementary students, often have difficulties in identifying and utilizing evidence, as well as articulating their reasoning (Erduran et al., 2004; McNeill, 2011; Sampson & Clark, 2008).

Argumentation as a Form of Social Practice

Situating ourselves in social constructivism, we contend that knowledge is constructed through social interactions (Vygotsky, 1978). From this perspective, we adopt the view of argumentation as a form of social practice (Kim & Roth, 2014; Ryu & Sandoval, 2012). Scientific argumentation, as a form of social practice, focuses on the construction of knowledge about the natural world through the critique and revision of ideas using *evidence* (McNeill, González-Howard, Katsh-Singer, & Loper, 2016; Chin & Osborne, 2010). Evidence is at the core of scientific argumentation (McNeill, 2011; Sampson & Clark, 2008, 2009); aligning with previous studies in literature (e.g., Larrain et al., 2014), this study took the citation of evidence to support or rebut certain claims as indicators of the emergence of argumentation.

The Spontaneous Aspect of Argumentation

Studies that explore the spontaneous aspect of argumentation in classroom contexts, although they have been rare, support the possibility that student argumentation occurred spontaneously in science classrooms (Kim & Roth, 2018; Larrain et al., 2014). With quantitative methods, Larrain et al. (2014) sketched the panoramic view of argumentation in middle-school science lessons, which were "developed … based on routine curricular material" (p. 1024). Larrain et al. (2014) reported that argumentation between students in routine science classes was observable, yet not as frequent as argumentative conversations between teachers and students. Their study provides important information around the spontaneous emergence of argumentation. But in view of the features and limitations of quantitative research, studies with qualitative methods are needed to gather more in-depth information as the authors stated that the "small-scale in-depth analysis studies…are crucial for improving our understanding of…the emergence of argumentation" (Larrain et al., 2014, p. 1018). Kim and Roth (2018) described the presence of argumentation in untutored classroom talks with qualitative methods. In this research, natural forms of argumentation such as making claims with evidence appeared spontaneously when 7- to 8-year-old children were engaged in problem solving situations. Kim and Roth (2018) revealed that scientific problem-solving context had the potential to initiate argumentative discourse, yet it is still not well known whether there exist any other factors contributing to the emergence of argumentation. Thereby, this study aims to further explore possible factors impacting the emergence of argumentation.

The Research

Research Context and Participants

This study took place in a Grade 5/6 science classroom in western Canada over a four-month period. One classroom teacher and 18 students participated in this study. The teacher valued an inquiry-based approach such as problem-based learning that has the potential to develop students' competence of critical and creative thinking and problem-solving (Kuhn, 2005). Within the research period, students first learned basic concepts about air, aerodynamics, and flight, such as how aircrafts fly with propulsion, drag, lift, and gravity. After that, the teacher organized and engaged them in group problem-solving. One example was a parachute design project: students worked in small groups to design, test, and revise their parachute models to meet the criteria that were co-constructed by themselves and the teacher (e.g., being able to land an egg to the ground from the 2nd floor of their school building). Students were encouraged and supported to work collaboratively to solve their problems. During the entire process, there was no argument-focused intervention. Within this context, we aimed to identify the spontaneous occurrence of argumentation.

Data Collection and Analysis

This study was framed as a qualitative case study (Merriam, 1998). For data collection, we employed systematic observation to capture students' spontaneous argumentative discourse. Systematic observation has the potential to provide a dense multi-variable description of the participants, and thus is informative for researchers (Desoete, 2008). Among six groups in class, three groups were chosen as focus groups based on their active verbal interactions and classroom participation. Each focus group included three students comprising a mix of genders (female and male) and ages (Grade 5 and 6). Over the course of 4 months, we observed and video-recorded all the science classes (27 in total) and took field notes. We also invited the focus groups for semi-structured interviews at the end of the research. Students from the same group were interviewed together and each interview lasted around 30-40 minutes. During those interviews, students shared their rationales for certain actions and how they perceived their group work and the teacher's support. With these multiple methods of data collection, we achieved data triangulation and thus, the validity of this study.

Data from these multiple resources were qualitatively analysed to provide corroborating evidence to locate major and minor themes (Creswell & Miller, 2000). Video recordings of classroom activities and interviews were transcribed and then crossed checked with the researchers' field notes to identify episodes of student argumentation. Specifically, we took the citation of evidence as the indicator of the emergence of argumentation. When evidence is cited to support or rebut certain claims, it indicates that an alternative position emerges, thus argumentation occurs (Larrain et al., 2014) (see table 1 for examples). With this criterion, we identified episodes of scientific argumentation. Next, these episodes were analysed with the *Coding Scheme for Students' Argumentative Discourses* that we developed for this study. Based on the claim-evidence-reasoning framework, we developed an initial coding scheme which was revised during the actual analyses. Table 1 shows the finalized version of the coding scheme. The analyses were conducted by each researcher individually, followed by an interactive video analysis to mitigate researchers' disagreements on coding results. Interactive video analysis requires that researchers view and interpret video clips together and critically and creatively examine each other's interpretations to reach consensus (Jordan & Henderson, 1995). Through interactive video analysis, our initial interpretations of students' argumentative practice were refined and finalized. Data analysis in this study was iterative. After interpreting the emergence and development of student argumentation our data analysis moved the next stage to analyze contextual aspects that influenced the emergence of argumentation. At this stage, the analysis was also initiallyconducted individually by each researcher. Then, the analysis results were further refined and finalized through our group discussions.

Table 1: Coding Scheme for Students' Argumentative Discourses

Category	*Description*	*Example*
Claim Making	Any claim proposed by students to solve problems	"we can use tissue paper [to make the canopy]"
Simple Support	Any attempt to defend or support a claim without citing any evidence	"I think that will work"
Support with Evidence	Any attempt to defend or support a claim with evidence (e.g., scientific knowledge, personal experience)	"… newspaper is better … because it can be very very big"
Simple Rebuttal	Any attempt to reject or challenge a claim without citing any evidence	"that is not a good idea"
Rebuttal with Evidence	Any attempt to reject or challenge a claim with evidence	"[…] we should also think about the gravity […] It would be very heavy for the bigger newspaper"

As argumentation has social elements at its core, Kelly, Druker, and Chen (1998) argue that students do not regularly describe evidence or articulate reasoning when it is "intersubjectively available and assumed to be understood" (p. 857). In other words, neither evidence nor reasoning is necessarily stated explicitly in a dialogical context. Therefore, our inference was involved when we attempted to interpret and understand student argumentation. Interviewing students was one way we achieved the credibility of our data interpretation (Guba & Lincoln, 1994), as during the interviews we queried, for example, students' rationales of certain statements. Moreover, for the credibility, we also discussed our inference during the interactive video analysis. Agreement on whether our inference was reasonable and to what degree our inference was acceptable, for example, was also achieved through our discussion.

Findings

The Spontaneous Emergence of Student Argumentation

Concerning the first research question—How does student argumentation spontaneously emerge in elementary science classrooms? —we found that students' spontaneous argumentative conversations frequently emerged in science learning, especially during their collaborative problem-solving. Examination of the classroom episodes of students' argumentation helped us discern that student argumentation often emerged when students challenged each other's ideas during problem-solving through questioning the rationales or proposing different solutions.

Peers' questioning initiated argumentation. During group work, students proposed possible solutions to solve their problems that became their claims. They often asked each other to justify the rationales of proposed claims. One student asked why such claims were made and the other needed to provide their justification with evidence. Through this type of dialogue exchange, argumentation took place to move forward their problem-solving. The following episode shows this notion. To preserve the anonymity of the participants, pseudonyms were used throughout this paper.

Episode #01: Designing a parachute canopy.Students in groups were to design, build, and improve parachute models. During the teacher-led classroom discussion, it was stated that the main goal for their parachute design was "to make it [the parachute] land to the ground as slowly as possible." With this goal, students started their design and building. While students in Group #01 were designing the canopy of their parachute model, the following dialogue took place, as per Table 2.

Table 2. Dialogue #01: "Why should [the canopy] be very big?"

Turn	*Students*	*Argumentative Discourse*
1-1	Adam:	we should make it [the canopy] as big as we can.
1-2	Brad:	Big? Why? … why should it be very big? […]
1-3	Adam:	That is because the bigger it is, the lift is stronger […] [then] it could stay in the air very long and land slow[ly]
1-4	Brad:	[nodding]
1-5	Cory:	Oh, I know how to make it big […]

Regarding how to make their parachute land to the ground slowly, Adam proposed that they should make the canopy "as big as they can" (turn 1-1). Brad then asked Adam about reasons for his claim (turn 1-2). With this questioning, Adam explained the rationale of his thinking. Specifically, Adam used scientific knowledge that they learned from the previous classes (i.e., in order for the devices to fly, they must have sufficient lift) to justify his claim (turn 1-3). Brad's questioning led Adam to provide the evidence of why a big size would reach their goal. Adam's justification with evidence was taken as the indicator of an alternative position, thus the emergence of argumentation. This short dialogue presents the possibilities of how argumentative dialogues spontaneously occurred when students challenged each other's ideas during their problem solving.

Group decision-making on solutions to solve their problems led argumentation. During the collaborative problem-solving, students sometimes proposed different possible solutions. To move forward their tasks, they needed to make their decision on which one they wanted to try and test. Students' attempts to achieve their agreement on group problem-solving led them to justify their own and/or rebutt others' proposals with evidence. In this way, argumentation emerged and could further develop. The following episode #02 was one of the illustrating examples.

Episode #02: Deciding the material for the parachute canopy. While designing the parachute model, students in Group #02 proposed different ideas about materials for their parachute canopy. After Kelvin asked the group "How about paper?", Jacob suggested they could use newspaper, while Peter proposed "we should use tissue paper". In this way, two different claims were expressed publicly within the group. With the aim to make their decision on the solution, Jacob and Peter started to justify their own claims through providing their evidence, thus argumentation between them occurred (see Table 3). Jacob suggested "newspaper … can be very big" (turn 2-1), yet Peter argued "tissue paper is light" (turn 2-2). Neither of them was persuaded, so their argumentation further developed as they continued justifying their own and started to rebut the opponent's claim. To be specific, Jacob firstly acknowledged Peter's idea was reasonable by saying "[being] light is important" (turn 2-3). However, he then cited the scientific knowledge they learned (i.e., "the bigger [the canopy is], the larger lift it will have in the air") to further back up his own proposal and pointed out that "being big" with newspaper "is […] more important" than being light with tissue paper (turn 2-3). To Jacob's words, Peter expressed his rebuttal as well. With his knowledge around how gravity influences aircraft in flight, Peter pointed out that the bigger newspaper as the canopy would have more gravity, which was not good for their parachute (turn 2-4). This episode showed that, when different possible solutions were coexisting in group problem-solving situation, students wanted to make their decision, on which they all agreed, regarding how to solve their problem. The decision-making process led them to provide evidence, justification and rebuttal, therefore, engage in argumentation.

Table 3: Dialogue #02: "Newspaper" VS "Tissue Paper"

Turn	*Students*	*Argumentative Discourse*
2-1	Jacob:	Let us think about it […] newspaper is better … because it can be very very big.
2-2	Peter:	[…] But tissue paper is light. Right? […] That will help [make our parachute land to ground slowly].
2-3	Jacob:	[Being] Light is important, but [being] big is also, like more important, if it is not big enough, it will fall down very fast. […] Remember, the bigger [the canopy is], the larger lift it will have in the air […]
2-4	Peter:	But the gravity … we should also think about the gravity. […] It would be very heavy for the bigger newspaper. […] tissue paper is light […]

Contexts that Impact the Emergence of Argumentation

In this study, we also questioned what contexts in classroom settings could help argumentation emerge. Understanding this may help develop appropriate instructional supports for students' learning about/through argumentation. Our data analysis revealed that students' appreciation of their group work and the teacher's scaffolding contributed to the emergence and development of argumentation.

Students' appreciation of group collaboration promoted argumentation. Interviews with students revealed that students appreciated the diverse ideas appeared during their collaboration. With this appreciation, when students encountered different ideas (e.g., claims and evidence), they were willing to learn their peers' thoughts by questioning and listening, and share theirs through explaining and justifying. In this way, students' positive attitudes towards collaboration and diverse ideas promoted the emergence of argumentation.

During the interview Fran from Group #03 shared that she "enjoyed group collaboration" and further elaborated why she thought herself a better learner in group work:

> …in the group work, you can get other people's thoughts instead of just your own…if you have one thought about a thing, maybe you can listen to others, maybe you will change your thoughts, because you think others' make better sense…have better reasons…when you are work individually, you are blocked off just by your own thoughts, instead, if you are in group work, you can remove that walls and communicate with others to see what they think. (transcript of student interview)

Students appreciatedthe diverse ideas raised during collaboration because they knew the benefits of learning others' thoughts, which were different from their own. Theyknew and believed that learning other ideas was helpful for them to improve their own ideasand update their own knowledge schema. They said this was how to become "a better learner." When they found "others make better sense" and "have better reasons" with more convincing evidence and reasoning, they were willing to revise their own thoughts or accept new ones. They understood how different ideas helped them to think more thoroughly and solve their problems further as a group. Another student, Jared, mentioned that "[they] always combined [their] thoughts together, and then, made [their] decisions," because "when you have this piece, and she has that [piece]…when you put them together… [you get] a whole picture" of the problem under investigation. With the appreciation of their collaboration and diverse ideas, students were willing to ask about each other's ideas and explanations, express their own thoughts, and cite evidence to either justify or rebut. In this way, argumentation between students emerged.

Teacher's scaffolding around collaborative problem-solving was critical. The teacher's instructional supports also facilitated students to challenge their peers and share their own thoughts with evidence. The teacher built the group problem-solving context in her science classroom as she organized and encouraged students to work collaboratively to solve certain problems. It was found that the majority of argumentation between students and their peers emerged during their collaborative problem-solving. Moreover, the teacher's scaffolds around collaboration (e.g., benefits of learning together with peers who might held different ideas) and the Nature of Science (NOS) (e.g., how scientists work and resolve disagreement) helped argumentation emerge and further develop. During the interviews, students shared how they recognized and appreciated these scaffolds. For example, Jacob mentioned that, "we talked in the class that when we have different ideas…we should say…this is the reasons…that is how scientists work…to get a better idea." Regarding why Brad challenged Adam's proposal in dialogue #01, Brad said, "I asked that question because we need to know *why* [he stressed this word] …She [the teacher] showed us…that [why] part matters … that is the effective collaboration … but we need to be respectful, we talked [that] in class …". According to what students shared, they recognized the teacher's scaffolds and acknowledged that these scaffolds influenced their thoughts and behaviors. With the teacher's scaffolding, they learnedthe significance of evidence to make the final group decision, therefore, they asked for and provided evidence during their group problem-solving. They also appreciated this way of collaboratively working/learning together, because the teacher told them "that is how scientists work."

What students shared in the interviews was consistent with our classroom observation. Within some classroom discussions, the teacher and students talked about how to work as a group with respect to each other's thoughts. What follows is an example. In this teacher-led whole-class discussion, the teacher encouraged students to question and respect each other's ideas.The teacher's scaffolding strategies influenced the emergence and development of argumentation in class.

Table 4: Dialogue #03: Teacher-led class Discussion

Turn		*Teacher-led Whole-class Discussion*
3-1	Teacher:	…we know that usually when we work as groups, sometimes, we have different ideas…so how do you think we can reach the agreement? We always need a final decision, right?
3-2	Student 1	...everyone in the group should have the chance to express, like say, this is what I think and this is why…

3-3	Student 2:	…we take the turn to say our ideas and we talk about [these ideas] …
3-4	Teacher:	Yes! We share our ideas and reasons and discuss…be respectful…this is how scientists think and do too…with evidence, they communicate…we do in the same way…think about what we can learn from each other's idea…

Conclusion and Discussion

As pointed out by Metz (2011), many scholars suggest that opportunities for elementary students to participate in scientific argumentation are typically "impoverished" (p. 51), as younger learners are assumed to have limited reasoning abilities, communication skills, and content knowledge necessary for argumentation (Lee & Kinzie, 2012). Yet, findings in this study argued that with appropriate scaffolding, elementary students are capable of participating in, and learning through, scientific argumentation.

Findings of this study also suggest that student argumentation can emerge spontaneously in classroom contexts without specifically-designed argument-focused interventions. Through examining the observed argumentative practice between students, we found the majority of the spontaneous student argumentation took place in the collaborative problem-solving context. When students challenged each other's proposed solutions with the aim of moving their problem-solving forward, they responded by justifying their own thoughts and/or rebutted different ones with the evidence they had in hand. When students did not fully understand their peers' words or had divergent viewpoints, they used questions, cited evidence, or explicitly expressed alternative proposals to challenge their peer's thinking (Chin & Osborne, 2010). By publicly communicating their puzzlements and rationales during argumentation, students pull together their ideas about the problem under investigation and make explicit claims including (mis)conceptions which their peers could respond to (Sampson & Clark, 2009). In this way, student argumentation and learning through argumentation took place naturally in the social problem-solving context in classroom setting. These findings suggest that particular argument-focused interventions might not be necessary to engage students in argumentative practice. Common or routine classroom practices such as problem-based learning, facilitating dialogic interactions such as sharing, questioning, and expressing alternative propositions help students engage in and learn through argumentation.

However, it is noteworthy that facilitating dialogical interactions in a productive way is by no means an easy task for teachers; instead, it requires much pedagogical preparation and consideration. In this study, it was found that the teacher's instructional supports, such as scaffolds around the NOS and scientific problem solving and emphases on collaboration in a respectful way contributed to students' appreciation of group work. Students' appreciation of their collaboration, which was represented by their willingness to share their own rationales and learn others' ideas by listening and questioning, made the dialogical interactions between students happen. In this way, the teacher's instructional supports facilitated the emergence of student argumentation and learning through participating in argumentation practice. In other words, findings of this study have supported that these specific scaffolds implemented by the teacher in this study were fruitful. However, given the limitation or nature of the research design of this study (i.e., qualitative case study), these scaffolds might not be generalized to other contexts (Guba & Lincoln, 1994). Future research is required to explore how specific scaffolding strategies support students' dialogical interactions and argumentation for critical thinking and problem-solving skills in various classroom contexts. Nevertheless, based on what was found, we would suggest, to facilitate learning through argumentation in science classrooms, it is important for teachers to develop effective problem-solving activities and reflect on what social norms could be established with students for effective collaboration such as how to raise questions and how to think about and evaluate other people's ideas critically and respectfully.

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