Exploring Current Practice of Using Technology to Support Collaborative Argumentation in Science Classrooms

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Abstract

The purpose of this qualitative study is to explore how middle school science teachers enact the practice of using technology to support collaborative argumentation in their science classroom. This study employs qualitative case study and drew on data sources of interviews and observations. This study identifies two themes. Six teachers regard scientific argumentation as an important science practice, but five of them integrate this practice into their science class without formally introducing it. All teachers integrate different forms of technology to engage students in scientific argumentation. The findings suggested there is a need to provide professional development for teachers to learn about scientific argumentation. The findings can be used as a basis for the design and development of professional development training experiences for in-service teachers.

Introduction

Recently, the Next Generation Science Standards (NGSS Lead States, 2013) identified scientific argumentation as one of the eight essential science practices for students. Scientific argumentation is a form of logical discourse that involves arriving at an agreed-upon position among members of a group (Andriessen, 2006) and is practiced when scientists build on and refute one another's theories and empirical evidence to arrive at scientific conclusions. Sampson, Enderle, and Walker's (2012) view of scientific argumentation is consistent with earlier views (e.g., Andriessen, Baker, & Suthers, 2003), but they expanded the definition of scientific argumentation and viewed it as a social and collaborative process of proposing, supporting, evaluating, and refining ideas to make sense of a complex problem to advance knowledge.

A number of researchers (Kuhn, 1993; Walton, 1996) have defined essential elements of argumentation: position, reason, evidence, counterargument, and rebuttal. Position refers to an opinion or conclusion about the main question that is supported by reason. Evidence is a separate idea or example that supports reason or counterargument/rebuttal. Counterargument refers to an assertion that counters another position or gives an opposing reason. Rebuttal is an assertion that refutes a counterargument by demonstrating that the counterargument is not valid, lacks as much force or correctness as the original argument, or is based on a false assumption.

In light of the reform efforts, researchers have used different approaches to develop curricula to help middle-school students hone argumentation skills in formal learning environments (Iordanou, 2010; Kuhn, 2010). For example, Crowell and Kuhn (2014) developed a collaborative argumentation curriculum in which 56 students (sixth, seventh, and eighth graders) attending an urban middle school with a predominantly Hispanic and African-American lower and lower-middle socioeconomic student population participated twice a week for three years in the experimental group. The control group participated in a traditional whole-class discussion. Crowell and Kuhn's (2014) findings indicated that the verbal argumentation skills of the experimental group outdistanced those of the control group in the final assessment.

Young adolescence is a critical age in which argumentation skills develop (Belland, Glazewski, & Richardson, 2011). Theoretically, young adolescents should be able to comprehend and construct arguments; however, empirical evidence does not confirm these expectations. Students usually provide insufficient or inconclusive evidence to support their arguments (Walton, 1996), have difficulty distinguishing evidence from explanation in support of a claim, or lack the ability to provide counterargument (Crowell & Kuhn, 2014). When asked to generate argumentation for or against their own positions, students typically provide more reasons to support their own position and fail to identify points of conflict to rebut others' argumentation (Crowell & Kuhn, 2014).

In the middle grades, science becomes more difficult and abstract. Piaget (1972) posited that children progress through four stages. At the sensorimotor stage (birth to 2 years old), the infant builds an understanding of himself or herself and reality through interactions with the environment. At the preoperational stage (ages 2 to 4), the child is not yet able to conceptualize abstractly and needs concrete physical situations. At the concrete operations stage (ages 7-10), the child begins to think abstractly and conceptualize, creating logical structures that explain his or her physical experiences. But according to Piaget's four stages of cognitive development, young adolescents (usually ages 10 to 15) should reach the fourth stage of cognitive development, the formal optional stage, and be able to logically use symbols related to abstract concepts, such as science. They should be able to think about multiple variables in systematic ways, formulate hypotheses, and consider possibilities. They should also be able to comprehend abstract relationships and concepts. However, middle-school students progress through the cognitive development stages at different rates, and some young adolescents might still be at the third stage of cognitive development, the concrete operational stage. They cannot think abstractly or hypothetically. Scientific argumentation can serve as a form of social negotiation and is a powerful force in the cognitive development of learners (Driscoll, 1994). Similarly, Bruner (1986) explains that learning is a communal activity or sharing of culture. By engaging in social negotiation, learners have the opportunity to share their understanding with others while others do the same with them. This provides multiple perspectives to each learner through a negotiation process between learners, resulting in better understanding and learning outcomes. Social negotiation provides opportunities for young adolescents to think hypothetically about the issues and assess multiple outcomes (Christie & Viner, 2005), which supports the development of abstract thinking and reaches the fourth stage of cognitive development, the formal optional stage.

Previous research on scientific argumentation (Crowell & Kuhn, 2014; Felton & Kuhn, 2001; Kuhn, Goh, Iordanou, & Shaenfield, 2008; Kuhn, Wang, & Li, 2010) has shown that integrating the instructional practice of collaborative scientific argumentation into the curriculum can lead to increases in students' scientific argumentation skills at the middle school level. Additionally, teachers' classroom uses of technology have become more and more prevalent and varied. It is believed that teachers' integration of technology into classrooms for higher-order tasks will ultimately lead to increased student learning (Trust, 2018). That is, higher-level technology use will enhance every aspect of students' learning experience across curricular areas so the students will grow intellectually rather than merely develop isolated technology skills. Hennessy et al. (2007) found that when teachers integrated technology to encourage students to engage in "What if" explorations in the science classroom, this practice resulted in supporting students' construction of links between scientific theory and empirical evidence; that is, collaborative scientific argumentation. Thus, this study aims at exploring the intersection of collaborative scientific argumentation and technology integration and to study how middle school science teachers enact the practice of collaborative scientific argumentation in their science classrooms with the support of technology. The following research question was addressed: How do middle school science teachers enact the practice of collaborative scientific argumentation in their science classrooms with the support of technology?

Literature Review

Collaborative Argumentation

Collaborative argumentation is a technique for arriving at an agreed-upon position among members of a group (Andriessen, 2006). Andriessen distinguished between debate and collaborative argumentation. In debate, students learn how to prevail over an opponent, which is an emphasis in the legal domain. Contrarily, collaborative argumentation is practiced when scientists build on and refute one another's theories and empirical research to arrive at scientific conclusions. In the classroom, students are typically engaged in collaborative argumentation activities in groups. In Suthers, Vatrapu, Medina, Joseph, & Dwyer's (2008) quasi-experimental study, for example, pairs of college-level physics majors from various geographic locations synchronously collaborated on a science challenge problem using an online application. The students began constructing an argument, saw a counterargument appear, and then began discussing the counterargument with its creator via the online application. In Authors' (2015) study, during the first two days of the collaborative argumentation activities, the students were allowed 40 minutes each day to engage in verbal collaborative argumentation with their team members pertaining to the question, "Which form of alternative energy is the best?" After each team came to a consensus about a form of alternative energy, each team used an online application to post reasons and evidence. Starting on the third day, inter-country argumentation was initiated. Each team from the US was paired with a corresponding country from Taiwan, with teams choosing distinct answers to the posed question. Each team read the opposing team's reasons and evidence and provided a counterargument in the online application. The teams then read the counterarguments, decided collaboratively how to rebut these counterarguments, and then posted their rebuttals in the online application.

Researchers have viewed collaborative argumentation as a key way in which students can learn critical thinking, reasoning, and problem solving (Cho & Jonassen, 2003; Jonassen & Kim, 2010). Kim, Anderson, Nguyen-Jahiel, and Archodidou's (2007) study examined collaborative argmentation among 10 groups of fourth and fifth graders in a text-based online system. Analysis of the students' argumentation showed that eight schemes were used by most groups. One example of the argumentation schemes is to manage participation of classmates by saying, "What do you think, NAME?" Once an argumentation scheme emerged, it tended to spread to other students and to last for the whole argumentation period. The spreading effects promoted students' learning of reasoning strategies and thinking skills. The other schemes include supporting or opposing other students' argumentation, validating other students' argumentation, extending the story world, and making the argumentation more explicit.

Researchers also viewed collaborative argumentation as a way in which students can develop individual argumentation skills (Felton & Kuhn, 2001; Kuhn et al., 2008; Kuhn, Wang, & Li, 2010). Kuhn and Udell (2003) found that a peer dialogue group showed increased frequency of powerful argumentation skills and an improved quality of individual argumentation compared to a non-peer dialogue group (13- to 14-year-olds). Crowell's (2011) study examined whether middle level students' (grades sixth, seventh and eighth) engagement in a three-year argumentation curriculum on social issues promoted development of argumentation skills, specifically the use of direct counterargument. Analysis of their essays and argumentation indicated that performance of the experimental group exceeded the control group. At the final assessment, the students in the experimental group demonstrated more sustained direct counterargument sequences than the students in the control group. Cho and Jonassen (2013) integrated collaborative argumentation strategies to help college level engineering students develop argumentation schemas. They found that collaborative argumentation groups generated more argumentation, more counterarguments, and more rebuttals. When engaged in collaborative argumentation, the students were able to develop and transfer argumentation schemas to new contexts. Additionally, research (e.g., Belland et al., 2011) has shown that collaborative argumentation leads to a broadening and deepening of argumentation by stimulating cognitive processes like elaboration, self-explaining, and rethinking concepts and is an effective strategy for learning argumentation skills.

Several studies (Carr, 2003; Easterday, Aleven, Scheines, & Carver, 2009) have explored the potential of collaborative argumentation for developing content knowledge and increased science achievement, resulting in mixed findings. Easterday et al. (2009) conducted a study in which the students learned how to engage in causal reasoning on public policy problems. The study compared the effects of three conditions under which students were asked to analyze a problem. These conditions included (a) problem presented as text only, (b) problem presented as text with an additional pre-made causal diagram, and (c) problem presented as text with a computer-assisted program that students could use to actively construct a concept map from the text. Scores on the transfer test were significantly better for students in the third condition. The authors' (2015) quasi-experimental study explored how seventh graders in a suburban school in the US developed argumentation skills and science knowledge in a project-based learning environment that incorporated a computer-assisted application. A total of 54 students (three classes) comprised this treatment condition and were engaged in collaborative argumentation that incorporated a computer-assisted application, while a total of 57 students (three classes) comprised the control condition and were engaged in collaborative argumentation without the computer-assisted application. This study concluded that collaborative argumentation incorporating a computer-assisted application was effective for improving students' science knowledge. Carr (2003), however, had contrary findings, indicating that a computer-supported environment is not necessarily better than traditional methods for promoting learning outcomes. In Carr's study, second-year law students in a treatment group worked on legal problems in small study groups with access to QuestMap, a computer-assisted program, while students in a control group either worked alone or in small groups without QuestMap. The students in the treatment group did not outperform those in the control group on the final exam.

Integrate Technology to Support Collaborative Argumentation

In this study, technology integration is broadly defined as the use of hardware such as laptops, scanners, smart boards, document cameras, digital cameras, digital camcorders, and Chromebooks, as well as related software and the Internet, in classrooms to enhance learning (International Society for Technology in Education, 2005). Research (Hsu, Van Dyke, Chen, & Smith, 2016; McCrory, 2006) has identified potential affordances of technology for supporting collaborative argumentation.

The first potential affordance, *representation*, refers to providing representations of ideas and processes that are difficult or impossible to characterize without technology. Examples include the use of online concept-map software to support collaborative argumentation (Author 2016; Suthers et al., 2008). Research shows that visualizing arguments graphically through a concept-map software enables students to see the structure of the argument, thus facilitating more rigorous construction and communication (Kiili, 2012).

The second potential affordance, *information*, refers to providing access to data and content on the Internet, such as earthquake data from around the world (Blank, Almquist, Estrada, & Crews, 2016). Another example is an online GIS tool, referred to as the H2OMapper. It is a watershed data management system designed to directly support teachers and students in studying middle school earth science (Baker, 2015).

The third potential affordance, *collaboration*, refers to facilitating communication and interaction with peers and experts. Specifically, interactive whiteboard (e.g., smart boards) studies were conducted in classroom settings but were primarily directed toward orchestration with a central teacher position emphasizing verbal interaction (Davidsen & Vanderlinde, 2016). Higgins, Mercier, Burd, and Hatch (2011) investigated the process of integrating multi-touch tabletops into teaching and learning activities and found that children tend to more positively collaborate in activities based on multi-touch tabletops than in paper-based tasks.

Pedagogical Beliefs and Technology Integration

Teachers' beliefs refer to the internal constructs that help them interpret experiences and guide specific teaching practices (Pajares, 1992). In teacher-centered learning, teachers believe they are the authorities of knowledge and a change in external behavior can be achieved through a large number of repetitions of desired actions (Skinner, 1938). Thus, teachers who have teacher-centered beliefs tend to believe in using technology for low-level learning, such as to teach remedial skills, and in using a single technology to support a lecture or other teacher-centered practices. On the contrary, according to constructivist learning beliefs, teachers are facilitators of the learning process as they support students' construction of their knowledge via collaboration or other engaging activities (Driscoll, 1994; Vygotsky, 1978). Thus, a number of studies (e.g., Ertmer, 2005; Levin & Wadmany, 2008; Mama & Hennessy, 2013) have suggested that teachers who have constructivist learning beliefs tend to believe that technology should be integrated more frequently for high-level learning such as engaging students in inquiry-based activities, collaborating with peers at a distance, supporting student activities such as problem-solving, and using multiple technologies such as spreadsheets and concept maps as well as presentation tools to organize information from the Internet. This study explored teachers' pedagogical beliefs about learning environments as well as their uses of technology in facilitating the practice of scientific argumentation.

Methods

This study used a qualitative research methodology, specifically case study research design (Stake, 1995), to explore answers to the research question. The first researcher was responsible for sampling the participants, collecting the data, and analyzing the data, while the second and third researchers assisted with the data analysis process.

Context and Participants

This study was conducted with teachers who taught in school districts that had a partnership with a large university in midwestern US. These school districts were located in the urban, suburban and rural areas within one to two hours of Chicago. In this study, the participants were limited to school science teachers in grades sixth to eighth (middle schools). The first researcher used a maximum variation sampling strategy to select six science teachers who had a range of teaching experience and represented five different school districts in diverse areas for interviews and observation. When the first researcher recruited the participants, the teachers all reported 1) their schools provided a cart of computers the teachers could loan out, and 2) they integrated technology into their instruction regularly. They were not considered significantly different from those who did not participate in the present study. Table 1 presents the demographics of the six science teachers. The names presented in Table 1 are pseudonyms. The schools denoted as low SES have more than 40% of students receiving reduced or free lunch.

Table 1.

Demographics of Six Science Teachers

Name	Gender (M/F)	Year of Teaching Experience	Grade Level	Location of School	Social-Economic Status (SES) of the School
Cathy	F	20	6th	Urban	Low
Leslie	F	6	6th	Rural	Low
Sam	M	1	6th-8th	Rural	Low
Mary	F	15	7th	Urban	Middle
James	M	7	8th	Suburban	Middle
Lucy	F	17	8th	Suburban	Middle

Data Collection

In-depth interviewing. The first author conducted two rounds of interviews at different points of time during the semester: one at the beginning of the semester and the other toward the end of the semester (see Appendix A). Interview questions were geared toward investigating how the six science teachers defined scientific argumentation and how they enacted this practice in their science classrooms. The interviews took approximately 60 minutes each. The first author used a digital recorder to record the interviews and then transcribed them.

Observations. Observations were the second source of data collection in this study. The first author asked each teacher to identify one unit of lessons that exemplified his/her best practice of engaging students in scientific argumentation process and positive integration of technology to support collaborative argumentation. The first author traveled to the schools and observed each teacher for a week. In this study, the first author adopted a list of five constructivist conditions for learning compiled by Driscoll (1994) and developed a checklist to analyze their practices:

1. Provide complex learning environments that incorporate authentic activity
2. Promote social negotiation as an integral part of learning
3. Juxtapose instructional content and include access to multiples modes of representation
4. Nurture reflexivity
5. Emphasize student-centered instruction

The first author also adopted Doering and Roblyer's (2010) view of technology in constructivism to analyze how each teacher integrated technology to enhance the scientific argumentation process and developed a checklist. The checklist includes fostering creative problem-solving and metacognition, building mental models and increasing knowledge transfer, fostering group cooperation skills, and allowing for multiple and distributed intelligences. Observation data were used to triangulate the interview data.

Data Analysis

In this multiple-case study, the researchers used a specific analytical strategy, cross-case synthesis, to analyze the six cases. The goal of cross-case synthesis is to retain the integrity of the entire case and to compare or synthesize any within-case patterns across the cases (Yin, 2018). First, we began identifying the within-case patterns. We conducted the analysis using two coders at two levels. We followed the coding method for qualitative inquiry outlined by Saldaña (2015), which prescribes a cyclical model that moves from codes to categories and eventually themes. In his method, methods in the first-cycle coding involved a more direct description of the data. We used data-driven codes and assigned a descriptive code such as ISA (importance of scientific argumentation), TSA (training of scientific argumentation), WSA (ways of introducing scientific argumentation), ITSA (involvement of technology to engage students in scientific argumentation), and TTSA (types of technology to engage students in scientific argumentation) to all data sources. We repeated the same procedure to assign all codes for all data sources of each participant in the first cycle. The second cycle coding entailed additional analytical processes such as classifying how the teachers integrated scientific argumentation as part of learning and how they integrated technology to support the scientific argumentation process. Second, after drawing some tentative conclusions about these within-case patterns, we continued to examine the relationships across the cases and developed themes. For example, based on the cross-case analysis, we identified how they integrated scientific argumentation as part of learning in their science classroom. Thus, we developed the first theme: Six teachers regarded scientific argumentation as an important science practice, but five of them integrated this practice into their science class without formally introducing it. We continued to develop the second theme, using the same procedure. The inter-rater reliability for the two levels of coding was approximately 80%.

Establishing Trustworthiness of Qualitative Data

This study adopted triangulation, peer debriefing, and thick description to ensure trustworthiness had been met (Lincoln & Guba, 1985). Multiple data sources, including interview transcripts and observation data, were compared to confirm the emerging findings. In peer debriefing, we consistently shared the emerging findings with each other and explained our thinking processes to each other to resolve disagreements. Additionally, we provided very detailed descriptive data to support the readers' decision making.

Findings

The purpose of this study was to explore how middle school science teachers enact the practice of collaborative scientific argumentation in their science classrooms with the support of technology. In this section, we present two themes. One theme is concerned with how the teachers integrated scientific argumentation into their science classroom and the other focuses on their use of technology to support scientific argumentation.

Theme one: Six teachers regarded scientific argumentation as an important science practice, but five of them integrated this practice into their science class without formally introducing it. All teachers regarded scientific argumentation as an important science practice. Cathy, a sixth-grade science teacher, defined scientific argumentation as a way for "students to state a claim and support it with evidence or data and then try to convince others to agree with the claim." She believed that scientific argumentation "will help students develop critical thinking skills and communication skills.” Leslie, a sixth-grade science teacher, shared the purpose of scientific argumentation with her students and said, “I keep telling them scientists don’t work just in the corner by themselves....It’s okay that you and I don’t agree, but we have a reason...you have to have some evidence. Science is about data and evidence.” As a science teacher in sixth through eighth grade, Sam’s definition of scientific argumentation was similar to Cathy’s and Leslie’s. As an eighth-grade science teacher, Lucy defined it as a way “to allow for conversation between the students to refine, question and allow for redefinition...more than a debate because it is evidence-based and not just with quantitative data but qualitative data.” Another eighth-grade science teacher, James, shared a similar definition and elaborated on the evidence in scientific argumentation: “The evidence is either the qualitative or the quantitative with the data they either collected through research or maybe they obtain through a lab setting.” As a seventh-grade science teacher, Mary’s definition of scientific aligned with Lucy’s.

However, Cathy also found that her students “initially struggle with being able to see another person’s perspective.” She recalled that “one year, I had them argue whether or not the US should adopt the metric system.” Leslie pointed out that one of the struggles the students had is “they don’t always understand they need to have the evidence to support their reasons,” and Sam shared a similar observation. Lucy elaborated the concern:

> It is definitely difficult for them initially. The hardest part is to get them to understand the abstract part by pulling the connection without telling them what the connection is. Showing them concrete models is helpful, but a lot of times it is like you still don’t get it. Sometimes even with models and the discussion, they still don’t make the connection and I don’t know how else to make that connection for them. How do you teach abstract thinking without telling them the connection? Guiding them to that thought process is always a challenge because everybody is different; their brains are all different in that aspect based on their background knowledge, what they know, what they understand from lab, the information they processed and caught, and what missing.

James shared his observation about students’ difficulty with reasoning and said, “The reasoning is the most difficult part for them, but that’s where they elaborate how their evidence supports their claim.” Mary’s observation echoed Cathy’s, Leslie’s, Sam’s, James’s, and Lucy’s.

Most teachers did not have any training in the practice of scientific argumentation and introduced the practice into their science classroom informally. Cathy integrated scientific argumentation spontaneously. She said, “I have not formally practiced argumentation in my classroom.” Although she was aware that scientific argumentation is one of the most important science practices in the Next Generation Science Standards (NGSS), she said, “I have not had any training or professional development addressing argumentation in the classroom.” Leslie said, “Many teachers may not do it formally or they may not call it scientific argumentation....I had an activity on scientific argumentation about alternative energy last year” and added,

> I collaborated with the language arts teacher. She taught the students about the structure and I just guided them to the topic or to the research of evidence. Scientific argumentation kind of pushes them to think about it a little bit more than just surface.

She also stressed she integrated this practice to engage students in science. She explained,

> Middle school science becomes more abstract. It is really important to maintain excitement and enthusiasm in science in the classroom. If you lose them in middle school, it’s done...Scientific argumentation would be helpful because students are getting away from the clear-cut definition to more inquiry or new investigation.

Sam did not learn scientific argumentation in college courses, but he learned it from his cooperating teacher while student teaching. The cooperating teacher was retired from a college faculty position. Lucy discussed her experience with learning scientific argumentation in different courses in college and said, “We have talked about how evidence should support your findings.” She discussed her approach teaching students through a scientific argumentation process and said,

> A lot of modeling, but also having concrete labs that support their findings like vary clearly at first. For example when we are studying chemical change, we take sugar cubes, we heat them up and we separate the carbon and the water vapor. They can definitely see that it's very concrete, it's very visual, it's very multi-sensory.

James learned the practice of scientific argumentation from a professional conference teaching about NGSS argumentation. Although James did not introduce this practice formally, he integrated both verbal and written forms of scientific argumentation when he saw fit. He said, "They are not going to be able to explain it in writing if they are not first verbalizing it out loud." Mary's experience is similar to James's. She learned scientific argumentation from a professional colleague at college and did not formally introduce this practice to her students.

Theme two: All teachers integrated different forms of technology to engage students in scientific argumentation.
Cathy involved students in playing a game when she engaged them in the scientific argumentation process. She regarded the game as a better way "to get the students more involved." In the activity, the student teams learned about all the energy sources and then were assigned to represent one specific energy source. Cathy projected the Great Energy Game Board onto the smart board, which fostered collaboration among students on the same team. The objective of the game was to be the first team to reach the top of the game board. The game was played in rounds. When they played the game, the team members looked at the game board on the smart board and developed scientific argumentation about the merits of their source versus the others. Specifically, each team was given the opportunity to move its token up by stating a reason or evidence for its energy source. They could alternatively choose to move an opponent's token down by stating a counterargument to the opponent's energy source.

Leslie implemented the unit of alternative energy for 10 days. She covered each form of alternative energy – solar, wind, and geothermal – for one day. Toward the end of the unit, she had student teams participate in a conference and had the other student teams observe the conference talks. Leslie used the smart board to facilitate the scientific argumentation process by showing the elements of scientific argumentation (e.g., reason, evidence, counterargument, rebuttal), which fostered collaboration on the student teams when discussing the reason and evidence for their assigned alternative energy and identifying counterarguments for the alternative energy of their opposing team. The two student teams sat face-to-face, and each team had a microphone. The student teams each gave a reason and evidence for why they thought their energy was positive. Then the student teams were given three minutes to come up with a counterargument to the opposing team's positive points in an attempt to score points for their team. For example, the geothermal group provided a counterargument to the biomass group. The biomass team had 30 seconds to prepare a rebuttal to the geothermal group's counterargument. The process was repeated for three rounds. Then they switched sides, and the biomass group offered a counterargument for geothermal. Leslie felt that overall the conference engaged the students. She also observed that "the practice really does help girls in scientific argumentation. I have noticed a shift in girls' confidence. They feel more secure what they know…. Boys just want to state the fact and that's over." Sam used a similar approach; however, Sam assigned the students to work in pairs, while Leslie formed student teams of three to four persons.

Lucy described her unit: "Moving toward NGSS we are starting to bring [the] real world into our classroom. The unit we are doing right now is a good example of that." In the observed lesson, she started a discussion about industrial evolution and CO_2 emission and how they are affecting the environment. Lucy assigned each student one task (e.g., recorder, group leader) and asked the student teams to test different fuel sources and explore alternative fuel sources other than fossil fuels. They discussed the pros and cons of the different alternative fuel sources. The student teams were engaged in scientific argumentation through using the data from their lab and the research they had completed with their Chromebooks. The students knew that biofuel does not work as well in the cold weather, which is a big stumbling block and could be evidence for a counterargument. But they also knew that bio-diesel produces less carbon dioxide. This unit really lent itself well to scientific argumentation. The Chromebooks afforded the student teams the ability to collaborate in the scientific argumentation process by accessing data and content on the Internet and using the data and content for reasons, evidence, counterargument, or rebuttals.

Mary's unit was similar to Lucy's. The biggest difference was that Mary used a computer-assisted program to support the scientific argumentation process. Each student team used Lucidchart, a concept-map type of a computer-assisted application, to present their arguments against a team without verbally talking to the other team. The visual representation of the concept-map type of application supported cognitive processes and allowed the students to make their thinking visible and to monitor the development of reason and evidence. Additionally, the visual representation also facilitated the sharing of cognitive load by providing support for developing reason and evidence as well as providing more resources for developing counterargument and rebuttals.

In the observed unit, James conducted a mini-unit on finches that lasted from Monday to Friday. The objective of the unit was to discover information about what may have caused a decline in the finch population on the island of Daphne Major. James presented the evidence collected by scientists with the document camera. The students worked in teams of three to four to determine what was causing the finches to die and used the data from the websites James provided for the reasons and evidence. Additionally, the students used this information to engage in scientific argumentation using evidence about why some finches die and why some do not. By working collaboratively, the student teams presented this information to the group and argued with one another based on the evidence they researched on a computer. Through the scientific argumentation, each student team came to a single conclusion of what was causing disruption of the finch population.

Discussion and Conclusion

All teachers regarded scientific argumentation as an important science practice and their views of scientific argumentation are consistent with earlier views of the scholars. All teachers defined scientific argumentation as a process of constructing an explanation based on evidence and of identifying solutions (Andriessen, 2006). To these teachers, scientific argumentation involved these young adolescents in a social negotiation process that motivated them to be engaged in science learning process.

Most teachers had not received formal training in the practice of scientific argumentation. In light of the reform efforts, researchers have used different approaches to develop curricula to help middle-school students develop argumentation skills in formal learning environments (Iordanou, 2010; Kuhn, 2010). However, it seems professional development for teachers in this specific practice is lacking. Most teachers learned this practice in a variety of informal ways through colleagues, professional conferences, or self-study. The lack of professional development might be the reason they did not formally introduce this practice in class. As pointed out by Driver, Newton, and Osborne (2000), the lack of teachers' pedagogical skills in organizing collaborative argumentation within the classroom and lack of opportunities for students' practice of collaborative argumentation within the classroom are significant impediments to establishing collaborative argumentation as a central activity in science education.

All teachers also pointed out the challenges in integrating scientific argumentation into their science classroom. Their observations are consistent with previous research (Belland et al., 2011; Crowell & Kuhn, 2014; Walton, 1996). Although these young adolescents seemed capable of developing reasons, they had trouble providing evidence to support reasons as well as providing the connection between reasons and evidence. Additionally, these young adolescents sometimes had difficulty seeing other's perspectives and might have failed to provide rebuttals and counterarguments. These difficulties might be attributed to young adolescents' cognitive development, which takes time to grow (Piaget, 1972). Because science becomes more difficult and abstract in middle schools, the use of collaborative scientific argumentation seemed to sustain young adolescents' interest in science and further engage them in science learning. Additionally, scientific argumentation seemed to involve young adolescents in inquiry-based investigation instead of clear-cut answers. With less emphasis on memorization of science facts, young adolescents might be open to choosing science as their career. Young adolescence is a critical age during which students decide whether they will pursue science as their career (Belland et al., 2011; Rapanta, Garcia-Mila, & Gilabert, 2013).

All teachers integrated collaborative scientific argumentation as part of science learning. All teachers involved their students in collaborative scientific argumentation through small groups. They also situated collaborative scientific argumentation in the context of authentic science issues, such as energy, and aimed at creating a student-centered learning environment. The learning environments created by these science teachers reflect a number of critical elements in constructivist learning environments (Driscoll, 1994); however, the teachers in low-income school districts tended to add playful qualities (e.g., a game board, a conference style) to engage their students in the development of scientific argumentation. Play is an important part of our mental and social development (Garvey, 1977; Herron & Sutton-Smith, 1971; Reaney, 2019), has great potential for connecting to inquiry-based research, and could be an effective way to employ collaborative scientific argumentation for students who come from low-income families and might not have a positive identity with science. Additionally, all teachers integrated technology to support the scientific argumentation process in a variety of ways. Consistent with the previous research (Davidsen & Vanderlinde, 2016; Higgins, Mercier, Burd, & Hatch, 2011), use of smart boards by all of the teachers afforded collaboration among the students in the scientific argumentation process. In the process, the teachers used smart boards to guide the students to articulate reasons, evidence, rebuttals, and counterarguments. In terms of affordance, three teachers used the internet to engage students in researching data in the scientific argumentation process. Among these three teachers, one teacher used concept-map software to support representation of scientific argumentation in the process. The students in these three teachers' science classrooms were able to use research findings and draw on multiple sources of data to support their argumentation in terms of evidence. These students came from middle-class or upper-middle-class families.

Overall in this study, the teachers integrated scientific argumentation through different topics (e.g., alternative energy, decline in the finch population). They also implemented scientific argumentation for different timelines (e.g., one day, one week, 10 days). Moreover, they used the elements of scientific argumentation in different ways. Some used evidence, reason, counterargument, and rebuttal, while others only used evidence and reason.

Because young adolescents sometimes have difficulty seeing other's perspectives and might fail to provide rebuttals and counterarguments, it is important to provide professional development on strategies to guide students in developing counterarguments and rebuttals. In terms of use of technology, it could be helpful to introduce professional development on the types of technology and to discuss what affordance each type of technology could offer to support the scientific argumentation process. Using technology to guide students to represent scientific argumentation in concept-map software seems to be a new practice for teachers although this practice has showed potential in facilitating students' development in scientific argumentation in current research (Author, 2016).

In this study, the findings suggested a need to provide professional development for teachers to learn about scientific argumentation, specifically formal instruction addressing the elements of scientific argumentation with which young students are struggling. The findings can be used to design and develop professional development training experiences for in-service science teachers and pre-service teachers.

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Appendix A

1. What is your definition of scientific argumentation?
2. How do you enact this practice in your classroom (e.g., writing, science talk, what topics, in pairs, in groups)?
3. How did you learn this practice?
4. How have you prepared your students to learn this practice?
5. How do you assess students' scientific argumentation skills?
6. Have you experienced any issues when integrating this practice in your classroom?
7. Have the students experienced any issues when you integrate this practice?