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Science Teachers' Views of Argument in Scientific Inquiry and Argument-Based Science Instruction

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Abstract
This study is aimed at examining science teachers' views of argument in scientific inquiry and argument-based science instruction. Questionnaires were collected from 53 middle and high school science teachers in the metropolitan area of the Republic of Korea. More than half of these respondents seemed to have a clear understanding of argument in scientific inquiry defining argument as the "discussion of scientific facts and data." Although most teachers seemed to understand the relationship between argument and scientific inquiry, a relatively small number of teachers identified laboratory experiments for a topic of argument-based science instruction. While more than half of these teachers simply viewed "deriving and coordinating various ideas" as a role of argument in science class, some teachers perceived "promoting student learning" as a role of argument including "expanding student thinking," "experiencing of scientific knowledge construction," and "learning scientific knowledge." Of the 13 teachers who had implemented argument-based science classes, nine stated benefits of argument in science class such as "student solving problems on their own," "student sharing ideas and considering various perspectives," "student thinking improvement," "high class participation," and "high student interest." Most of these respondents commented on the difficulties and challenges in implementing argument-based science instruction such as a lack of time and student argument ability. Teachers who did not implement argument-based science instruction gave reasons related to teachers themselves (lack of experience, understanding, and teaching skills), students (lack of experience, knowledge, and willingness to participation), and the learning environment (lack of class time, entrance exam–oriented class, and number of students).

Keywords Argument · Scientific inquiry · Argument-based science instruction · Science teachers

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Introduction

Scientific literacy has been proposed as an important goal of science education (NRC 1996, 2013). Scientifically literate citizens should be able to not only understand scientific knowledge but also obtain, evaluate, and communicate scientific information (Norris and Phillips 2003). While recognizing the central role of argument to the concept of science, Osborne (2002) emphasized the importance of student engagement in argument while doing science to improve scientific literacy. Students should be engaged in generating questions about natural phenomena, designing investigations, proposing claims, providing evidence based on data obtained from the investigation, and engaging in argument from evidence (Cavagnetto 2010; NRC 2013). Though the Korea National Science Curriculum has also emphasized the importance of scientific literacy and argumentation in inquiry-based science investigations (Ministry of Education 2015; Ministry of Education, Science, and Technology 2009), reports by the Korea Institute for Curriculum and Evaluation (2008) indicated that only ten to 30 % of class time in Korea was spent on student talk, discussion, and argumentation about the topic while the average percent for OECD countries was about 80 (Lee 1998). Thus, it would seem that there are fewer opportunities for Korean students to engage in argumentation in the science classroom. There might be various reasons for such lack of student engagement in argument in Korean science classes, including teacher adherence in covering the Korea National Science Curriculum, emphasis on college (university) entrance examinations, student–teacher ratios, and lack of argument-based science activities within designated teaching materials. More importantly, science teachers' views of argument in scientific inquiry and argument-based science instruction play a critical role in their decision to plan and implement an argument-based science lesson. Although there are research studies examining teachers' views on scientific inquiry and inquiry-based science lessons or teachers' understanding of argument structure, less is known about teachers' views of argument as a core activity of scientific inquiry and argument-based science instruction (Cho et al. 2008; Gillies and Nichols 2015; Lee et al. 2009; McNeill and Knight 2013; McNeill et al. 2016; Sampson and Blanchard 2012; Shin and Choi 2014; Tseng et al. 2013; Wallace and Kang 2004). In this respect, the present study is aimed at examining Korean science teachers' views of argument in scientific inquiry and argument-based science instruction. This study could provide implications for science teacher education programs regarding teacher knowledge and practices of argument-based inquiry investigations.

Argument in Scientific Inquiry

Argument is a core practice of scientific inquiry. It consists of generating inquiry questions, planning investigations, collecting and analyzing data, and drawing conclusions (Driver et al. 2000; Duschl and Osborne 2002; Ford 2008; McNeill and Pimentel 2010; Sampson et al. 2011). In science, argument supported by evidence plays a significant role in constructing explanations of natural phenomena (Jiménez-Aleixandre and Erduran 2007). Driver et al. (2000) have distinguished between *logic* (defined as an academic discipline that presents decontextualized rules for relating premises to conclusions) and *arguing* (perceived as a human practice situated in specific social settings). McNeill and Pimentel (2010) have defined argumentation in both structural and dialogic aspects. The structural aspect refers to argument as justification of knowledge claims using evidence and reasoning. The dialogic aspect refers to argumentation as persuasion or interactions that occur between individuals about the validity of their knowledge claims. That is, argument as a social activity is a negotiated social act within a specific community. Scientific knowledge is constructed through continuous arguments among scientists (Ford 2008; Hodson 2014). Thus, engaging in scientific argumentation is important for students to develop epistemological perspectives of science and learn scientific knowledge (Driver et al. 2000).

Authentic science learning could be achieved by engaging in argument based on scientific claims and evidence while doing scientific inquiry, not by just passively memorizing knowledge presented by teachers (Driver et al. 2000; McNeill and Knight 2013; NRC 2013; Osborne et al. 2004). Instead of focusing on just explaining concepts, laws, theories, and models, science teachers should provide students with opportunities to engage in argument embedded in scientific inquiry. In a review of argument interventions in K-12 contexts, Cavagnetto (2010) also noted that students should be engaged in scientific argument as part of doing scientific investigations to foster scientific literacy. For instance, the Science Writing Heuristic (SWH), which incorporates verbal and written argument into scientific inquiry, could be used as a framework to help students construct scientific knowledge within scientific inquiry (Keys et al. 1999). Sampson et al. (2011) proposed that Argument-Driven Inquiry (ADI) can be used as a template or guide to design laboratory activity that provides opportunity for students to participate in argumentation embedded in scientific inquiry practices. Studies have shown that the SWH or ADI approach is effective in improving student conceptual understanding, cognitive engagement in science, and argument ability (Hand et al. 2004; Keys et al. 1999; Walker and Sampson 2013). However, to successfully implement an argument-based inquiry approach such as SWH or ADI, teachers should adopt a facilitator role rather than the traditional authoritative one (McNeill and Pimentel 2010; Mork 2005).

Science Teachers and Argument-Based Science Instruction

Teachers' understanding and perceptions about teaching strategies or methods can influence whether their teaching strategies or methods are used in the class (Kagan 1992; Kang 2008). In a study investigating the implementation of argumentation by secondary science teachers who attended a series of professional development programs over a 1-year workshop, Simon et al. (2006) found that teachers' initial understanding of argumentation determined their implementation. Tseng et al. (2013) have explored science teachers' perspectives on inquiry teaching and reported that there are three different perspectives of inquiry: inquiry as thought, inquiry as process, and inquiry as competency. Asay and Orgill (2010) have criticized that teachers simply view scientific inquiry as process skills rather than a vehicle for learning science. The Next Generation Science Standards issued by the National Research Council used the term *practices* instead of a term such as *science processes* or *inquiry skills* (NRC 2013). The Next Generation Science Standards describe eight practices that are essential for science learning as follows: asking questions; developing and using models; planning and carrying out investigations; analyzing and interpreting data; using mathematical and computational thinking; constructing explanations; engaging in argument from evidence; and obtaining, evaluating, and communicating information (NRC 2013). This description suggests that students in science classrooms should participate not only in hands-on laboratory work but also in argumentation as part of the process of scientific inquiry that is essential for science learning. In order to facilitate students to engage in argumentation embedded in scientific inquiry, teachers should understand the logic and rationale behind scientific inquiry and be explicit about scientific inquiry practices (McNeill and Krajcik 2008). With respect to this, examining science teachers' understanding of argument as an essential feature of scientific inquiry could provide important implications on science teacher education to further develop their understanding of scientific inquiry practices.

Newton et al. (1999) identified teachers' concerns about using argumentation in their science lessons, including time constraints, heavy content load of the national curriculum, difficulties in managing discussions, and the lack of teachers' relevant pedagogical skills. Sampson and Blanchard (2012) investigated teachers' views about integrating argumentation into science teaching and learning. They reported that teachers considered that argumentation could help students learn science, but had concerns about students' low argumentation ability. In a study examining teachers' pedagogical content knowledge regarding scientific argumentation, McNeill and Knight (2013) reported that the design of argumentation learning tasks is challenging for teachers particularly when they develop argumentation questions to provide students with opportunities to engage in argumentation. They argued that teachers need more resources and tools to help them better integrate argumentation into their classroom practice.

Several research studies have examined teachers' views of scientific inquiry and inquiry teaching (Gillies and Nichols 2015; Tseng et al. 2013; Wallace and Kang 2004). Recent studies have also examined teachers' understanding of argument structure and pedagogical content knowledge of argumentation (McNeill and Knight 2013; McNeill et al. 2016; Sampson and Blanchard 2012). However, less is known about how teachers view argument in regard to scientific inquiry and argument-based science instruction. Recent reforms have emphasized the role of argument in scientific inquiry (NRC 1996, 2013), and a number of studies emphasize that constructing persuasive and convincing claims coordinated by evidence and theory is an important component of scientific inquiry (Driver et al. 2000; Duschl and Osborne 2002; Sampson and Clark 2008). Teachers' beliefs about argument in scientific inquiry can act as a critical factor influencing whether and how they design and implement argument in their science classrooms (McNeill and Krajcik 2008; McNeill et al. 2013). However, there have been few studies examining science teacher perspectives of argument as a core activity of scientific inquiry. Lee et al. (2009) reported that science teachers were unfamiliar with the terminology *argument in science*. Thus, we are interested in examining how Korea science teachers' views of argument as a core activity of scientific inquiry as the Korea National Science Curriculum emphasized written and verbal argument (Ministry of Education 2015; Ministry of Education, Science, and Technology 2009).

The most recent Korea National Science Curriculum requires K-12 science teachers to implement written and verbal argument and inquiry-based activities in science classrooms (Ministry of Education 2015; Ministry of Education, Science, and Technology 2009). Despite an emphasis on scientific literacy and scientific inquiry, studies report that there are few science classrooms in Korea where science teachers implement argument-based inquiry investigations (Cho et al. 2008; Lee et al. 2009). If a teacher thinks that argument-based science instruction is inefficient or ineffective for supporting students' science learning, he or she will most likely not plan or implement argument-based pedagogies. In this respect, examining teachers' perspectives on argument-based science instruction could inform teacher education programs so that they can improve teacher pedagogical content knowledge and practices on argument-based inquiry instruction.

Research Methods

Participants

This study surveyed 53 middle or high school science teachers (Tm = Teacher, middle school; Th = Teacher, high school) in the metropolitan area of the Republic of Korea. These participants were selected by convenience sampling (Patton 2002). The survey was distributed to 72 science teachers of 11 different middle or high schools. The response rate was 74% (53/72). Background information of these participants is shown in Table 1.

A total of 14 (26%) teachers, including six (29%) middle school teachers and eight (25%) high school teachers, had experienced argument-based science classes either during pre-service teacher education programs or in-service teacher professional development programs. Eight teachers had experienced an undergraduate argument-based science course, three teachers had experienced it in graduate school, and four teachers had experienced it through in-service teacher professional development programs. One teacher reported two different experiences in two different programs. None of these teachers experienced an argument-based science class during their elementary, middle, or high school days.

A total of 13 (25%) teachers, including five (24%) middle school teachers and eight (25%) high school teachers, had implemented an argument-based science lesson in their classroom. A total of 37 (70%) teachers, including 14 (67%) middle school teachers and 23 (72%) high school teachers, had never implemented an argument-based science lesson in their science classrooms.

Data Collection

We developed and conducted a questionnaire for this study. In order to develop the questionnaire, the first and third authors referred to research studies concerning teacher perceptions on argumentation and inquiry-based science instruction (Cho et al. 2008; Lee et al. 2009; McNeill and Knight 2013; McNeill et al. 2016; Sampson and Blanchard 2012) and discussed what

Table 1 Background information of 53 participating science teachers

		Number (%)
Sex	Male	19 (35.8)
	Female	34 (64.2)
School level	Middle school	21 (39.6)
	High school	32 (60.4)
Teaching experience	1~5 years	18 (34.0)
	6~10 years	14 (26.4)
	11~15 years	5 (9.4)
	16~20 years	6 (11.3)
	21~25 years	4 (7.5)
	Over 25 years	6 (11.3)
Education	Bachelors	29 (54.7)
	Masters	22 (41.5)
	Doctorate	2 (3.8)
Major	Physics	12 (22.6)
	Chemistry	25 (47.2)
	Biology	12 (22.6)
	Earth Science	4 (7.5)

questions should be included in the study's questionnaire. To increase the likelihood that participants would remain engaged with the full questionnaire, we limited the number of questions less than 10. Survey questions were as follows:

1. Please describe your experiences of argument-based science classes in your K-16 education as well as teacher education and professional development programs.
2. What do you understand by the term "argument in scientific inquiry"?
3. What is the relationship between argument and scientific inquiry?
4. What topics would be appropriate for argument-based science instruction?
5. What would the role of argument in science class be?
6. Please describe previous experiences of argument-based science instruction.

    6.1 What were the benefits of implementing argument-based science instruction?
    6.2 Did you have any difficulties in implementing argument-based science instruction?
7. If you have not implemented argument-based science instruction, please give the reason.

All questions were descriptive and open-ended so that participants would have the freedom to express themselves without limit. Participant teachers responded to the questionnaire in Korean and we translated these answers into English.

Data Analysis

Teachers' answers to these descriptive questions were analyzed using a constant comparative method, which "allows the researcher to differentiate one category/theme from another to identify properties and dimensions specific to that category/theme" (Corbin and Strauss 2008, p. 73). Our study attempted to differentiate properties and dimensions specific to teachers' views of argument in scientific inquiry and argument-based science instruction.

After the initial review of data, the first and the third authors of this study developed a list of codes and revised them through multiple iterations of data analysis. We reviewed all sets of data using a preliminary coding scheme and discussed any discrepancies in these codes until consensus was achieved. We then combined and grouped these codes into initial categories based on similarity and dissimilarity. By comparing these initial codes and categories, we identified a final set of codes and categories of teachers' views of argument in scientific inquiry and argument-based inquiry instruction. Two researchers of the present study met to elaborate these codes and categories and discussed any variations until consensus was achieved. The frequency of each code was also calculated. Total frequency is greater than the number of respondents because some responses fall into more than two codes.

Findings and Discussion

Argument in Scientific Inquiry

Teachers' responses on the relationship between scientific inquiry and argument were divided into those who reported a relationship between scientific inquiry and argument and those who did not understand links between argument and scientific inquiry, as shown in Table 2. Among responders who reported a relationship between scientific inquiry and argument, there were three different patterns: (1) argument is one domain of scientific inquiry; (2) argument is critical throughout the entire process of scientific inquiry; and (3) scientific inquiry develops through argument. Among responders who did not consider that there is a relationship between scientific inquiry and argument, there were two different patterns: (1) argument is separated from scientific inquiry and (2) I am uncertain about the relationship.

A total of 20 (38%) teachers commented that "argument is one domain of scientific inquiry." These teachers seemed to understand argument as one of various domains making up scientific inquiry. Half of middle school teachers commented that

> Tm3: Argument is one form of scientific inquiry.
> Tm15: Argument is a component of scientific inquiry such as observation, measurement, and experiment.

A total of 16 (30%) teachers commented that "argument is critical throughout the entire process of scientific inquiry." The teachers seemed to understand the importance and necessity of argument for all procedures of scientific inquiry.

> Tm13: Argument is used throughout all steps of scientific inquiry.
> Tm18: Argument is necessary in recognizing and exploring a problem.
> Th29: The process of argument is necessary when setting a hypothesis or analyzing data and errors of experiment results.

A total of 15 (28%) teachers commented that scientific inquiry could develop through argument. The following statements indicate that these teachers understand that inquiry can be expanded and developed through argument (Ford 2008; Osborne 2014).

> Th8: [Students] expand scientific knowledge through argument and perform more objective and rational exploration.
> Tm10: Argument can modify and supplement the inquiry process.
> Th1: Argument leads to a more reliable inquiry result.

Of the 53 teachers who responded to the questionnaire, 45 (85%) seemed to understand a relationship between argument and scientific inquiry as shown by their statements such as "argument is one domain of the scientific inquiry," "argument is critical throughout the entire process of scientific inquiry," and "scientific inquiry develops through argument." Argument

Table 2 Relationship between argument and scientific inquiry (unit: number (%))

Category	Code	Middle school teacher ($N = 21$)	High school teacher ($N = 32$)	Sum ($N = 53$)
Argument is related to scientific inquiry	Argument is one domain of scientific inquiry	11 (52)	9 (28)	20 (38)
	Argument is critical throughout the entire process of scientific inquiry	4 (19)	12 (38)	16 (30)
	Scientific inquiry develops through argument	3 (14)	12 (38)	15 (28)
Argument is not related to scientific inquiry	Argument is separate from scientific inquiry	2 (10)	0 (0)	2 (4)
Do not know	I am not certain	3 (14)	3 (9)	6 (11)

has been recognized as a core practice of scientific inquiry. It plays a significant role in constructing explanations of natural phenomena in science (Driver et al. 2000; Duschl and Osborne 2002; Ford 2008; Jiménez-Aleixandre and Erduran 2007; NRC 2013; Osborne 2014; Sampson et al. 2011). In this respect, we argue that both "argument is critical throughout the entire process of scientific inquiry" and "scientific inquiry develops through argument" demonstrate a more detailed and articulate understanding than the statement that "argument is one domain of scientific inquiry." Lotter et al. (2007) have found that teachers' beliefs about science, their students, effective teaching practices, and the purpose of education influence the amount and type of inquiry instruction in their classrooms. Furthermore, Johnson (2009) has found that teacher beliefs about instructional strategies impact their willingness to use inquiry-based instruction in their classroom. In a study determining the relationship between teachers' views and their teaching practice, Capps and Crawford (2013) report that teacher views of inquiry-based instruction are reflected in their teaching practice. In this regard, science teachers who understand when argument can be utilized and what the function and role of argument are in scientific inquiry and are aware of what needs to be discussed are more likely to actively facilitate argument-based scientific inquiry than those who merely understand that argument is a part of scientific inquiry. As suggested by the Science Writing Heuristic approach (Keys et al. 1999), discussion and argumentation could be implemented in each step of the scientific inquiry process. Argument among peers is encouraged in order to set up research questions, design investigation procedures, collect and analyze data, propose claims, provide evidence, and draw conclusions. Argument can be actively utilized in science classes if teachers recognize the importance and roles of argument in each stage of scientific inquiry (Keys et al. 1999).

Two (4%) teachers commented that "argument is separated from scientific inquiry." A total of six (11%) teachers, including three (14%) middle school teachers and three (9%) high school teachers, were uncertain about the relationship between scientific inquiry and argument. Teachers who responded that "argument and scientific inquiry are separate" and "I am uncertain about the relationship" did not understand the relationship between argument and scientific inquiry. Teachers who fail to understand the importance and roles of argument will not plan or guide student engagement in argument in inquiry-based science classes (Park and Oliver 2008).

There are four patterns (presenting personal opinions, discussion of personal opinions, providing scientific facts and evidence, and discussion of scientific facts and evidence) in teachers' definition of argument in scientific inquiry as shown in Table 3. Those teachers who mentioned "using scientific facts and evidence" (34, 64%) seemed to understand the importance of data and evidence in scientific inquiry compared with "using his/her opinions" (17, 32%). Recent studies on science education have reported that science teachers have difficulty in articulating why their evidence supports their claims (McNeill and Knight 2013; Sampson and Blanchard 2012). This means that reasoning based on data and evidence may be challenging for teachers. Our study also supports results of previous studies in that some science teachers could not recognize scientific facts and evidence as important components of argument in science.

A majority (44, 83%) of the participating teachers seemed to understand the meaning of argument in scientific inquiry as "discussion of scientific facts and evidence" or "discussion of his/her opinions" rather than simply as "presenting personal opinions" or "providing scientific facts and evidence." A total of 30 (57%) teachers defined argument in scientific inquiry as the "discussion of scientific facts and evidence."

Table 3 Meaning of argument in scientific inquiry (unit: number (%))

Category	Code	Middle school teacher ($N = 21$)	High school teacher ($N = 32$)	Total ($N = 53$)
Using his/her opinions	Presenting personal opinions	1 (5)	2 (6)	3 (6)
	Discussion of his/her opinions	8 (38)	6 (19)	14 (26)
Using scientific facts and evidence	Providing scientific facts and evidence	1 (5)	3 (9)	4 (8)
	Discussion of scientific facts and evidence	10 (48)	20 (63)	30 (57)
Do not know		1 (5)	1 (3)	2 (4)

Tm14: Discussing scientific facts with evidence
Th10: Explaining and persuading by using scientific principles and theory
Th7: Talking and discussing using evidence and reasoning about observed phenomenon

Argument in scientific inquiry is an activity of justifying claims and evidence and critically evaluating and discussing them with colleagues (Jiménez-Aleixandre and Erduran 2007; Sampson and Blanchard 2012). Results of the present study indicate that more than half of these teachers have an adequate understanding of the meaning of argument in science.

As argued by Ford (2008), the significance of argumentation lies in “dialectic between construction and critique.” Duschl and Osborne (2002) have also claimed that argumentation is fundamentally “a dialogic event carried out among two or more individuals” (p. 55). They have emphasized that the important dialogic aspect of argumentation is negotiating ideas through interactions with others. Argument is not only expressing personal opinion but also discussing his/her ideas while listening to others. A total of seven (13%) teachers simply mentioned that argument in scientific inquiry was “presenting his/her own opinion” (3, 6%) and “providing scientific facts or evidence” (4, 8%).

Tm2: Presenting the best ideas
Tm8: Drawing rational conclusions
Th22: Making hypotheses and conclusions
Th30: Providing scientific facts using scientific thinking

Teachers who stated that argument in scientific inquiry was “providing scientific facts and evidence” seemed to understand the importance of evidence in science. However, they lacked the understanding of argument in terms of negotiation (Duschl and Osborne 2002; Ford 2008). In addition, two (4%) teachers stated that they did not know the meaning of argument in the field of science. It would be difficult to expect teachers who have an insufficient understanding of argument in science to facilitate argument engagement, like using evidence and reasoning to construct and negotiate claims.

Role of Argument in Argument-Based Science Instruction

The question concerning the role of argument in argument-based science instruction was answered by a total of 35 teachers, including 12 middle school teachers and 23 high school teachers. As shown in Table 4, a total of 20 (57%) teachers commented that “deriving and coordinating various ideas” was the role of argument in science instruction.

Table 4 Role of argument in science class (unit: number (%))

Code	Middle school teacher ($N = 12$)	High school teacher ($N = 23$)	Total ($N = 35$)
Deriving and coordinating various ideas	5 (42)	15 (65)	20 (57)
Expanding student thinking	6 (50)	6 (26)	12 (34)
Experiencing construction of scientific knowledge	3 (25)	3 (13)	6 (17)
Learning scientific knowledge (law, principle, theory)	2 (17)	1 (4)	3 (9)
Promoting student motivation	0 (0)	2 (9)	2 (6)
Others	0 (0)	5 (22)	5 (14)

Tm7: [The role of argument is] respecting others' ideas and understanding that there are other opinions.
Tm19: [The role of argument is] being aware that people have different ideas through group discussion.
Th7: I expect my students to listen to and respect other opinions and incorporate different opinions.

A total of 12 (34%) teachers indicated that argument in science played a role in "expanding student thinking." These teachers understood that argument in science class could serve as a way for students to engage in scientific thinking and develop logical and critical thinking.

Tm8: I think it helps improve student scientific thinking.
Tm5: It seems to play a role in expanding scientific and critical thinking.
Th7: It helps develop students' scientific thinking ability.

A total of six (17%) teachers indicated that the role of argument in science instruction was "experiencing construction of scientific knowledge." They recognized the role of argument in science classes as a way for students to construct scientific knowledge as scientists would do in science (Driver et al. 2000; Duschl and Osborne 2002).

Tm11: [The role of argument is] experiencing the process of constructing scientific knowledge.
Th2: [The role of argument is] constructing scientific knowledge through social consensus.

A total of three (9%) teachers identified "learning scientific knowledge, theories, principles, and laws" as the role of argument in the science class. The following comments indicate that these teachers realize that students can achieve a deeper understanding of science topics and learn new scientific knowledge through argument.

Tm7: [The role of argument is] acquiring new knowledge.
Th25: [The role of argument is] obtaining accurate scientific knowledge through sharing ideas, listening to others, and engaging in argument.

As students are unable to learn science by simply doing hands-on activities (Hodson 2014), opportunities for students to engage in argument are key to bring about the breadth of conceptual understanding of science. Teachers who mentioned "expanding student thinking," "experiencing construction of scientific knowledge," or "learning scientific knowledge" seem to understand the value of argument in argument-based science instruction. Previous studies

(Capps and Crawford 2013; Johnson 2009; Lotter et al. 2007) insist that teachers' beliefs about science influence the type of inquiry instruction used in their classrooms. It is expected that teachers may be more likely to implement argument in science class if they can recognize the role of argument for cultivating student learning such as "expanding student thinking," "experiencing construction of scientific knowledge," and "learning scientific knowledge." Berland and Reiser (2009) have suggested three overlapping goals of argumentation: (1) constructing claims and explanation, (2) presenting arguments, and (3) critiquing and evaluating counter ideas while defending their own. Teachers who mentioned "deriving and coordinating various ideas" seemed to develop a comprehensive interpretation of argumentation.

Implementing Argument-Based Science Lesson

A total of 36 teachers, including 13 middle school teachers and 23 high school teachers, responded to the open-ended question about appropriate topics/themes for argument-based science instruction. As shown in Table 5, a total of 10 (28%) teachers mentioned "laboratory experiments" such as "experiment-based lessons," "establishing hypotheses, designing experimental procedures, and drawing conclusions," and "collecting evidence from experimental data." A total of nine (25%) teachers stated that topics related to society and technology would be appropriate. A total of five (14%) teachers suggested that appropriate topics could include controversial ones such as "choosing positive/negative opinions and claiming their opinions" and "discussion on the pros and cons." Four (11%) teachers responded that all topics would work for argument-based science instruction. A total of four (11%) teachers identified "history of science" as an appropriate topic for argument by stating "I think it would be appropriate to have students to experience the things that scientists have experienced."

It is interesting that the majority (85%) of respondents understood the relationship between argument and scientific inquiry as shown in Table 2. However, only 10 (28%) teachers considered laboratory experiments as topics for argument-based science instruction. It seemed that the majority of teachers recognized topics other than laboratory experiments for argument-based science instruction. This might be due to the style of activities provided in Korea science curriculum science textbooks that most science teachers use for their science teaching. Studies examining science textbooks in Korea report that science laboratory experiments included in science textbooks lack "asking questions," "engaging in argument from evidence," and "obtaining, evaluating, and communicating information" among eight scientific practices identified by the Next Generation Science Standards (Choi and Choi 2016; Jeon and Choi 2016; NRC 2013). It would be difficult to expect science teachers, who use such science

Table 5 Topics for argument-based science instruction (unit: number (%))

Code	Middle school teacher ($N = 13$)	High school teacher ($N = 23$)	Sum ($N = 36$)
Laboratory experiments	4 (31)	6 (26)	10 (28)
Society and technology topics	2 (15)	7 (30)	9 (25)
Controversial topics	1 (8)	4 (17)	5 (14)
All topics	4 (31)	0 (0)	4 (11)
History of science topics	2 (15)	2 (9)	4 (11)
Topics in science curriculum	1 (8)	1 (4)	2 (6)
Others	1 (8)	5 (22)	6 (17)

textbooks, to consider laboratory experiments to plan and implement argument-based science instruction.

Of the 13 teachers who had implemented argument-based science lesson, only nine teachers commented the positive aspects about implementing argument-based science lesson. Table 6 presents benefits of implementing argument-based science instruction that these nine teachers identified. The total frequency is greater than the number of respondents because some responses fall into more than one code. "Students solve the problem on their own" was commented as a positive aspect by a total of six (67%) teachers as shown in Table 6. Two (50%) middle school teachers and one (20%) high school teacher stated that students can share their ideas and consider various perspectives, for example, "students think in various perspectives," "students present various thoughts," and "students share ideas with each other." Two middle school teachers also indicated that student thinking improvement is a benefit of argument-based science instruction. They made comments such as "it helps students develop their thinking ability" and "students engage in scientific thinking." Two teachers mentioned that high class participation is a benefit of argument-based science instruction. They reported that student participation increased in argument-based science class by stating "argument-based lessons are effective to reduce the number of marginalized students" and "argument-based lessons increase student participation rate through group discussion." In addition, two high school teachers stated that "student interest in argument-based science instruction is high." They reported that students were more interested in an argument-based science lesson as "students were excited and actively involved" and "students were more interested in it."

Table 7 shows the difficulties in implementing argument-based science instruction identified by a total of 11 teachers (four middle school teachers and seven high school teachers) out of the 13 teachers who had implemented argument-based science lesson. "Lack of class time" was cited the most, by a total of six (55%) teachers. Teachers reported that they did not have enough time to implement an argument-based science lesson.

Tm12: It takes a long time to implement an argument-based science lesson.
Th29: It is difficult to encourage in-depth student argument due to time constraints.

In addition, a total of five (46%) teachers mentioned that there was a lack of students' ability to engage in scientific argumentation.

Tm12: Argument-based science lessons could only be led by high performing students.
Tm17: Students simply express memorized knowledge rather than engage in argumentation.

Table 6 Benefits of implementing argument-based science instruction (unit: number (%))

Code	Middle school teacher ($N=4$)	High school teacher ($N=5$)	Total ($N=9$)
Students solve problems on their own	2 (50)	4 (80)	6 (67)
Students share ideas and consider various perspectives	2 (50)	1 (20)	3 (33)
Improvement of student thinking	2 (50)	0 (0)	2 (22)
High class participation	1 (25)	1 (20)	2 (22)
High student interest	0 (0)	2 (40)	2 (22)
Others	0 (0)	1 (20)	1 (11)

Table 7 Difficulties in implementing argument-based science instruction (unit: number (%))

Code	Middle school teacher ($N = 4$)	High school teacher ($N = 7$)	Total ($N = 11$)
Lack of class time	2 (50)	4 (57)	6 (55)
Lack of student argument ability	2 (50)	3 (43)	5 (46)
Others	0 (0)	4 (57)	4 (36)

Th26: It is difficult for students who lack sufficient content knowledge to make conclusions through argument.

Some high school teachers also mentioned that students might develop misconceptions when they engaged in argument or that it was difficult to manage the class because of students who did not engage in argument.

Of the 13 teachers who had implemented argument-based science instruction in their classrooms, four teachers only mentioned difficulties or challenges without stating benefits. Teachers' negative perspectives and failures in regard to a certain teaching strategy could lower their self-efficacy and likelihood of using it in future classes (Bandura 1997). A teacher who only experiences difficulties or challenges in implementing argument-based science instruction would not likely to continue using it. Teachers who had positive experiences in argument-based science classes in their own schooling, pre-service teacher education programs, or in-service professional development programs might try to overcome difficulties if they encounter problems or difficulties in their own science classrooms. Therefore, science educators need to provide professional development programs that can help science teachers have positive and successful experiences of argument-based science instruction so that teachers will make an effort to adopt argument in their classrooms.

Table 8 shows reasons why 14 middle school teachers and 23 high school teachers had not implemented argument-based instruction. These reasons were grouped into three categories in terms of teachers, students, and environment. For reasons related to teachers, lack of teacher understanding of argument-based science instruction was mentioned by a total of six (16%)

Table 8 Reasons for not implementing argument-based science instruction (unit: number (%))

Category	Code	Middle school teacher ($N = 14$)	High school teacher ($N = 23$)	Total ($N = 37$)
Teacher	Lack of experience	1 (7)	3 (13)	4 (11)
	Lack of understanding	4 (29)	2 (9)	6 (16)
	Lack of teaching skills	0 (0)	6 (26)	6 (16)
	Difficulties in designing argument-based science instruction	1 (7)	2 (9)	3 (8)
Student	Lack of experience	1 (7)	0 (0)	1 (3)
	Lack of knowledge	1 (7)	5 (22)	6 (16)
	Lack of willingness to participate	2 (14)	0 (0)	2 (5)
Environment	Lack of class time	7 (50)	14 (61)	21 (57)
	Entrance exam–oriented education	0 (0)	2 (9)	2 (5)
	Number of students per class	0 (0)	2 (9)	2 (5)
	Lack of teaching materials	0 (0)	2 (9)	2 (5)
	Others	3 (21)	4 (17)	7 (19)

teachers. These teachers seemed not to have sufficient information or knowledge about argument-based science instruction.

Tm9: I lack the understanding of argument-based science lessons.
Th8: I am not familiar with argument-based science classes, do not know what it is, and have not experienced it as a teacher or student.

In addition, six high school teachers reported that the lack of teaching skills for implementing argument-based science instruction was the reason why they did not try to implement argument-based instruction.

Th1: I lack teaching skills to lead student argument.
Tm19: I do not know how to implement effective argument-based science lessons.

Four (11%) teachers also stated that "lack of experience of argument" was the reason. Teachers' comments such as "lack of my experience in argument" and "lack of own experience in argument-based science classes" indicated that these teachers were not confident in using argumentation in their classrooms because they lacked such experiences of argument themselves. A total of three (8%) teachers stated that "difficulty in designing argument-based science lessons" was the reason. Teachers' comments indicated that preparing and implementing argument-based science lessons were difficult and challenging for them.

Th3: It is not easy to prepare and design a lesson using a new approach.
Tm10: It is challenging for me to select topics of argument and evaluate student learning regarding the topics.

As for reasons related to students, a total of six teachers stated that students did not have sufficient content knowledge. Teachers' comments such as "lack of students' knowledge" and "students" knowledge level is not high enough to do any logical and scientific argument' implied that the lack of students' knowledge was the reason why they did not try to implement argument-based science instruction. Some teachers mentioned that argument-based science lessons would be effective for high-achieving students, but would be totally ineffective for low-achieving students. In addition, one teacher mentioned students' lack of experience of argument. While these teachers were concerned about students' content knowledge and lack of argument experience, teachers who had implemented argument-based science instruction also identified students' lack of ability to engage in scientific argumentation to be challenging (see Table 7). Students' ability to engage in scientific argumentation is related to both their content knowledge and argument experience. Two teachers also mentioned "students' lack of willingness and motivation" was the reason for why they did not implement an argument-based science instruction. Some teachers who had implemented argument-based science instruction in their classroom also reported the difficulty of managing the class due to students who did not engage in argument.

As for reasons related to the learning environment, "lack of time" was mentioned by a total of 21 (57%) teachers. Teachers claimed that "I don't have enough time to cover all the materials in the science curriculum" or "I don't try a new method due to the pressure to cover all material in the science curriculum." A lack of class time was also mentioned as a challenge by teachers who had implemented argument-based science instruction (see Table 7). There were also other comments by high school teachers such as "there is the burden of standardized tests and college entrance examinations" (two teachers) and "it was difficult because of the large number of students in a class (two teachers) and insufficient materials for class" (two teachers). In addition, a few teachers mentioned that "learning science content is more important than engaging in argument" and "argument-based science instruction is impossible."

Conclusion and Implications

Students should actively engage in argument embedded in scientific inquiry for authentic science learning (Ministry of Education 2015; Ministry of Education, Science, and Technology 2009; NRC 2013). In order to accomplish this goal, improving teachers' understanding of argument in scientific inquiry and argument-based science instruction should be prioritized. Our study shows that some teachers misunderstand that argument is separate from scientific inquiry or do not know about this relationship. Even if they understand the relationship between argument and scientific inquiry and the meaning of argument in scientific inquiry, teachers' understanding of argument in scientific inquiry varies in clarity and scope. The emphasis of argument as a core activity of scientific inquiry from the Korea National Science Curriculum seems to be insufficient for science teachers to realize the importance of argument-based inquiry investigations and implement it in their science classrooms (Cho et al. 2008; Lee et al. 2009).

Science teachers are unlikely to implement argument-based science lessons or stimulating students to engage in argument embedded in scientific inquiry if they do not understand the place or role of argument in scientific inquiry, do not recognize the importance and benefits of argument-based science instruction, or have insufficient efficacy in argument-based science instruction (Bandura 1997; McNeill and Knight 2013). Findings of this study suggest that science educators should support pre-service and in-service science teachers to develop a clear understanding of argument as a core activity of scientific inquiry. Findings also imply that it is necessary to provide science teachers with training programs that help them develop concrete and in-depth understandings of argument, including both structural and dialogic aspects of argument as well as understanding of nature of science, which makes science different from other disciplines (Driver et al. 2000; McNeill and Pimentel 2010; NRC 2013).

While a majority of teachers seem to understand the relationship between scientific inquiry and argument, it was interesting that a relatively small number of teachers considered laboratory experiments to be topics of argument-based science instruction. It would be difficult for teachers who are used to confirmation-type laboratory activities to plan or implement argument-based scientific inquiry that includes generating questions about a natural phenomenon, designing investigations, proposing claims, providing evidence based on the data obtained from the investigation, and engaging in argument from evidence. In our study, none of the teachers experienced argument-based science instruction during their elementary, middle, or high school science education. It is evident that science teachers without experience of argument in their school science classes are unlikely to implement argument-based science instruction in their own science classrooms. Inquiry-based science teaching would be challenging for teachers who are used to more traditional styles of science teaching. It is then somewhat surprising that we found that only 25% of the teachers reported implementing argument-based science instruction in their science classes. Science textbooks and teaching materials, including laboratory and inquiry activities in which arguments are embedded, need to be developed for science teachers for classroom use. Findings of our study also imply the necessity of professional development programs that can help teachers experience argument-based inquiry investigations and design and implement argument-based science instruction.

A science teacher is more likely to design an inquiry-based science lesson if he/she believes students' engagement in argument and scientific inquiry is likely to help them learn science (Kang 2008; Wallace and Kang 2004). In this study, a majority of teachers who implemented argument-based science instruction recognized the benefits of argument-based science instruction, such as "students solving problems on their own," "sharing ideas and considering various perspectives," "student improvement in thinking," and "high class participation." Teachers' successful experiences of argument-based science instruction would influence them to implement teaching strategy in their future lessons (Bandura 1997). Therefore, teachers who have succeeded in argument-based science instruction and recognized its benefits with respect to student learning would be more likely to guide students to learn science through argument-based science instruction in their future science lessons. Instead of providing short-term lecture-based programs without class-based practices, long-term teacher training programs and professional development programs that require participant teachers to plan and implement argument-based science instruction and discuss their experiences along with observations of student learning are needed.

Most respondent teachers in the present study commented upon difficulties and challenges in implementing argument-based science instruction, such as lack of time and student argument ability. Among the 13 teachers who had implemented argument-based science instruction, four teachers only mentioned difficulties without stating benefits. Unsuccessful experience and a lack of teaching skills would presumably lower teachers' self-efficacy and negatively impact their commitment to implement argument-based science lessons. Teachers who did not implement argument-based science instruction described reasons related to their own experience and expertise (lack of experience, understanding, and teaching skills), students (lack of experience, knowledge, and willingness to participation), and the learning environment (lack of class time, entrance exam-oriented class, and number of students). Emphasis on college entrance examinations in Korea likely provide a partial explanation for findings of this study as high school teachers are more concerned about class time, entrance exam–oriented class, and teacher-student ratios than middle school teachers. The teacher who experiences difficulties and challenges in implementing argument-based science instruction may not make efforts to plan or implement it. Findings indicate that teachers in this study were more concerned about factors related to their expertise and teaching context than students' abilities to engage in argument-based activities. This study indicates that it is necessary to provide professional development programs to help teachers gain positive experiences of argument-based science instruction and develop pedagogical content knowledge and efficacy in relation to argument-based science instruction so that they are willing to design and implement argument-based science instruction (McNeill and Pimentel 2010).

This study was conducted with a small sample of middle and high school teachers in the metropolitan area of the Republic of Korea. Thus, caution is needed when generalizing results of this study to other teachers. As we used only questionnaires to find out teachers' understanding of argument in scientific inquiry and their perceptions of argument-based science instruction, this study also has a limitation in that in-depth information was not gathered from interviews outside of the questionnaire and the findings are reliant on teachers' self-report data. Further research is needed to determine how teachers with superior understanding of argument in scientific inquiry implement argument-based science instruction in Korea and other similar cultural contexts.

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