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Exploring Korean Middle School Students' View about Scientific Inquiry

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ABSTRACT
The aim of this study is to examine Korean middle school students' view about scientific inquiry with the Views about Scientific Inquiry (VASI) questionnaire, an instrument that deals with eight aspects of scientific inquiry. 282 Korean middle school students participated in this study, and their responses were classified as informed, mixed, and naïve. The results revealed that Korean middle school students primarily held mixed or naïve views about scientific inquiry. To discover why students held these views, their responses were analyzed in detail. For instance, they did not understand the meaning of 'experiment', 'scientific', 'data', and 'evidence' well. They understood scientific terminology and scientific inquiry in everyday contexts. Students also tended to regard science process skill as scientific method. According to the results mentioned above, explicit and reflective instruction is necessary to develop students' views about scientific inquiry.
Keywords: NOSI (Nature of Scientific Inquiry), scientific inquiry, Korean middle school students

INTRODUCTION

The importance of inquiry in science education has been emphasized over the past few decades. Most nations emphasize doing inquiry (AAAS, 2009; NGSS Lead States, 2013), and this has been reflected by scientific curriculum that has aimed to develop scientific literacy (Akeben, 2015). The national science curriculum in Korea also highlights the value of inquiry. The 2009 revised curriculum in Korea, recently revised, presented science process skills and scientific methods as independent units. In addition, Korea's scientific textbooks presented student-centered activities that allowed students to experience inquiry processes.

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State of the literature

- Inquiry and laboratory investigation have become an important topics in science education around the world.
- In recent research and scientific curriculum reform documents, a growing emphasis has been placed on views about the nature of scientific inquiry.
- Recently, scientific education researchers have investigated the views of teachers and learners on the nature of scientific inquiry..

Contribution of this paper to the literature

- Using the Views about Scientific Inquiry (VASI) questionnaire, provides evidence that Korean middle school students hold views that range from naïve to informed view about the nature of scientific inquiry.
- Offers deeper insight into students' views about scientific inquiry.
- Estimates how science curriculum and the use of science terminology can affect students' views about scientific inquiry.

While the importance of inquiries has been emphasized consistently, knowledge about scientific inquiry, which is known as the Nature of Scientific Inquiry (NOSI), has only been emphasized in recent research and curriculum reform (Bartels, Lederman & Lederman, 2012; Pace & Farrugia, 2014; Senler, 2015). The NRC (2000) distinguished the differences between 'doing inquiry' and 'understanding inquiry'. The 2009 revised science curriculum in Korea referred to the importance of understanding the NOSI. The NOSI contains various methods that facilitate the understanding of aspects of inquiry (dealing with data, designing experiments, establishing hypotheses, communicating results, and forming explanations with current scientific knowledge) and knowledge about inquiry (data and evidence are different, scientists use various scientific methods, and similar procedures do not guarantee similar results) (Bell et al., 2003). Understanding the NOSI is critical and essential for performing and developing scientific inquiry (Hodson, 2008; Lederman et al., 2013). Beyond the basic inquiry skills, contemporary understandings about scientific inquiry allow students to recognize where scientific knowledge and scientific method originates (Schwartz et al., 2008).

The NOSI has often been included in the Nature of Science (NOS), not distinguishing between NOSI and NOS (Lederman, 2007). Views about the NOSI have merely been presented in the form of one or two items on questionnaires about the NOS. Regardless, many researchers have argued that the NOSI should be distinguished from the NOS (Lderman, 2007; Bartos and Lederman, 2014). NOS describes the characteristics of science. In particular, the NOS refers to the nature of scientific knowledge (Lederman, 2006). By contrast, NOSI emphasizes the process of scientists' inquiry that explore how scientific knowledge has been created, developed, and accepted (Schwartz et al., 2008; Lederman, 2014).

Several researchers (Dudu, 2014; Gaigher et al., 2014) have explored teachers' and students' perspectives on the NOSI. However, in contrast to the study of the NOS, there have yet to be a sufficient number of studies about the various perspectives on the NOSI (definitions, characteristics, teaching methods, and the expected impacts of scientific inquiry). In addition, while there has been a great deal of research on the NOS in Korea for the past several decades (Kang, Scharmann & Noh, 2005; Kim & Nehm, 2011), research about the NOSI has been relatively insufficient. Despite the importance of inquiry, research designed to facilitate an understanding of the epistemological view of scientific inquiry, or a proper understanding of scientific inquiry, has only been conducted recently (Park, 2007).

Therefore, because of the lack of related studies, analyzing students' views of NOSI is warranted. Investigating the students' aspect of the NOSI can provide a baseline of learners' understanding about scientific inquiry and interpret results of Korean science reform curricula. Such a baseline results can inform teacher and police makers in future educational planning towards developing students' understanding about scientific inquiry.

Purpose of the study

The purpose of this study was to investigate Korean middle school student's view about the scientific inquiry. The results of this study will provide baseline data for the design of new curriculum and explain how scientific inquiry may be reflected in future curriculum or instruction. The primary research question in this study is as follows:

1. What are the Korean middle school students' views on the Nature of Scientific Inquiry (NOSI)?

Scientific Inquiry

The definition of inquiry in science education is as diverse as much as the methods behind scientific inquiry themselves (Schwartz, Lederman & Crawford, 2004). Roth (1995) described authentic scientific inquiry as the activities that scientists practice every day. Bybee (2000) argued that scientific inquiry consists of the following three elements: skills of scientific inquiry, knowledge about scientific inquiry, and an educational approach for teaching science content. Schwartz (2004) referred to scientific inquiry as characteristics of the processes in which scientific knowledge is developed, accepted and used. In general, scientific inquiry is defined as scientific methods or activities that represent the characteristics of scientific processes. Scientific inquiry extends beyond the science process skills such as observation, classification, prediction, establishing hypothesis, and interpreting data (Lederman et al., 2014). Scientific inquiry combines these science process skills with scientific knowledge, scientific reasoning and critical thinking (Lederman, 2006, Senler, 2015).

Scientific inquiry has become the national curriculum standard in most countries (American Association for the Advancement of Science, 1993; Council of Ministers of Education of Canada, 1997; National Research Council, 1996; Turkish Ministry of National Education, 2005; Korean ministry of national education, 2007), and curriculum documents around the world, such as the National Science Education Standards (NSES), have referenced it for the instruction of the science.

[Inquiry] involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (NRC, 1996, p. 23)

Scientific inquiry has been a core idea in Korea's curriculum for the science, and developing the ability to conduct inquiry was highlighted in the objectives of the recently revised curriculum (Ministry of Education, Science and Technology, 2009; Ministry of Education, 2015). In the 2009 revised curriculum document about scientific educational goals, it was stated that students would be able to learn the fundamental concepts of science by investigating its nature and developing the ability to conduct scientific inquiries. In addition, the curriculum referred to learning that was based on various activities for scientific inquiry (e.g., surveys, discussions, experiments, observations, etc.). The curriculum also promoted certain teaching methods and practices that relate to scientific inquiry, which can be summarized as follows: basic inquiry processes (e.g., observation, classification, measurement, prediction, and inference) and integrated inquiry processes (e.g., formulating problems, hypothesizing, controlling variables, interpreting data, drawing conclusions, and making generalizations) should be taught so that they relate to teaching content.

The 2015 revised curriculum document also emphasized the ability for students to perform scientific inquiries as one of the primary goals of scientific education. Moreover, the curriculum stated that a considerable variety of inquiry-based learning techniques should be practiced (Ministry of Education, 2015). The ability to perform scientific inquiry was defined as the collection of data, the interpretation and evaluation of evidence through experimentation, and the investigation and discussion of results to gain new scientific knowledge or to construct new scientific meaning (Ministry of Education, 2015).

Recent Korean science textbooks, which follow the 2007, 2009, and 2015 revised curriculum, have covered science process skills and scientific methods. Textbooks provide students with the opportunity to experience student-centered inquiry activities.

Nature of Scientific Inquiry

The NOSI refers to the characteristics of the scientific processes through which scientific knowledge developed, accepted, and utilized (Schwartz, 2004). While the NOSI can be considered to be a part of the NOS, it is a separate concept that places greater emphasis on the inquiry practices of scientists. The NOS means values and beliefs about scientific knowledge only (e.g., the facts, laws, principles, and theories) (Lederman, 1992). Most views about the NOS are composed solely of features related to scientific knowledge (Vhurumuku & Mokeleche, 2009). By contrast, the NOSI is relevant to the process of scientific inquiry (Schwartz et al., 2008), and reflects characteristics of the scientific inquiry that are linked to the construction of scientific knowledge (Deniz & Akerson, 2013). The NOSI signifies the processes and component of scientific investigation and methods that are used to explain knowledge (Schwartz, 2007). It involves individual's understanding about scientific inquiry process, the way of scientific knowledge developed and justified, and what scientists really do (Vhurumuku & Mokeleche, 2009). In summary, the NOS is comprised of beliefs about scientific knowledge, and the NOSI is comprised of beliefs about the scientific inquiry process.

Next Generation Science Standards (NGSS Lead States, 2013) have highlighted skills and knowledge that are related to scientific inquiry. The specific aspects of scientific inquiry are described below:

(1) Scientific investigations all begin with a question and do not necessarily test a hypothesis
(2) There is no single set of steps followed in all investigations (i.e. there is no single scientific method)
(3) Inquiry procedures are guided by the question asked
(4) All scientists performing the same procedures may not get the same results
(5) Inquiry procedures can influence results
(6) Research conclusions must be consistent with the data collected
(7) Scientific data is not the same as scientific evidence
(8) Explanations are developed from a combination of collected data and what is already known.

The goal of the science education curriculum reform is changing from transferring of knowledge to development of scientific literacy through inquiry-based learning all over the world (Liu et al., 2012). Because scientific inquiry is an essential and fundamental part of scientific literacy (Schwartz et al., 2002; Deniz & Akerson, 2013; Lederman, Lederman & Antink, 2013), recent curriculum reform has emphasized both scientific inquiry process skills and knowledge about scientific inquiry (NRC, 2000). Adequate and sophisticated views on scientific inquiry allow people to better understand the science and scientific inquiry, and can further aid them in their ability to make better decisions on socio-scientific issues.

Research on Views of NOSI

Many researchers have investigated students' views on scientific inquiry, and most research has presented the idea that the NOSI is a part of the NOS. While researchers have used the Views of Nature of Science Questionnaire (VNOS; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002) or Science and Scientific Inquiry' (SUSSI; Ling, 2008) questionnaire to explore views about the NOS and the NOSI, most of these questionnaires have been designed to primarily explore common perspectives about the NOS.

According to previous studies of NOSI included in NOS, many students have lacked informed perspectives about the NOSI (Lederman, 1992; Lederman, 2007; Deniz & Akerson, 2013; Pace & Farrugia, 2014). For instance, Maltese undergraduates who attended the University of Malta held naïve to transitional views about the NOS and the NOSI (Pace & Farrugia, 2014). Undergraduate learners in both the sciences and non-sciences also responded similarly to most of the components about the NOS and NOSI (Pace & Farrugia, 2014). By comparison, the majority of U.S. middle school students held traditional views about the NOSI, and the majority of Turkish middle school students held naïve views about the NOSI (Senler, 2015).

Some researchers have concentrated on teachers' knowledge of the NOSI included in NOS. Their research proved that while some teachers held well-informed perspectives on the NOSI (Abd-El-Khalick, 2002; Dudu, 2014), most teachers held inadequate or naïve perspectives about the NOSI (Abd-El-Khalick, 2006; Linneman et al., 2003) and found it difficult to help their students develop informed views about the NOSI (Lederman, 1992; Minstrell & van Zee, 2000).

As NOSI becomes more important, the Views of Scientific Inquiry questionnaire (VOSI; Schwartz, 2004; Schwartz et al., 2008) was developed to assess understanding about the NOSI separating from NOS. Some studies (Senler, 2015; Ayndeniz et al., 2011) the VOSI questionnaire as an instrument that could measure various views about the NOSI. Lederman et al. (2014) revised the VOSI questionnaire and developed the Views about Scientific Inquiry (VASI) questionnaire, which is currently a critical component of research and curriculum reform, to provide a more exhaustive considerations about the characteristics of scientific inquiry. In addition, Lederman et al. (2014) deleted certain questions that served as icebreakers or that had been repeated from the VOSI questionnaire and added features about scientific inquiry that had initially been overlooked in the VOSI questionnaire. In order to identify validity, they also investigated the views of middle school students on scientific inquiry. Most of these students did not have informed views about scientific inquiry.

Gaigher et al. (2014) used the VASI instrument to evaluate how well South African students understood scientific inquiry. Among these students, the most understood aspect of scientific inquiry was the "agreement between conclusions and data." By contrast, the least understood aspect of scientific inquiry was the "multiple methods of science." Gaigher et al. (2014) also noted the differences between the socio-economic statuses (SES) of South African schools. Students who belonged to a higher SES held more informed and less naïve views about scientific inquiry. The peculiar aspect is the South African students had more informed view about scientific inquiry than students from other countries. Gaigher et al. (2014) explained that the Revised National Curriculum Statement (RNCS), which is currently taught at South African schools, reflects the several components of scientific inquiry very well. A majority of the targeted aspects of scientific inquiry have been clearly illustrated in the RNCS.

Scientists anticipate that students can develop their knowledge about scientific inquiry by doing inquiry activity. However, Students' knowledge about scientific inquiry does not advance by accident (Abd-El-Khalick et al., 2004). Previous studies have determined that knowledge about scientific inquiry does not develop through simple inquiry activities and that it is difficult to change pre-established views about scientific inquiry (Lederman, 2004). For instance, students who participated on an 8 week exhibited few changes in their views about scientific inquiry (Bell et al., 2003). Similarly, students who enrolled in a 7 month long explicit instruction course presented naïve to mixed and mixed to informed views about scientific inquiry and saw only marginal increases in their knowledge (Lederman et al., 2014). Thus, to develop students' views about scientific inquiry, teachers should be encouraged to carry out explicit and reflective instructions that are related to improving knowledge about the process (Abd-El-Khalick, 2001; Bell et al., 2003; Gaigher et al., 2014). Also participating in authentic scientific research (Aydeniz, Baksa & Skinner, 2011), being in work with scientists (Bahbah et al., 2013) are recommended to enhance students' view about scientific inquiry.

METHODS

Participants

The study focused on middle school students from an urban middle school in Cheong-Ju, South Korea. Grade 8, 282 students (male = 127; female = 155; mean age 15) from one middle school in South Korea participated in the study. Participants were from middle socioeconomic stats.

Data Collection

The VASI questionnaire, which was developed by Lederman et al. (2014), was selected for the collection of data. In order to examine Korean students' views about scientific inquiry, a Korean version of the instrument was developed. First, a researcher translated the instrument, and then two science education experts checked it over to determine that the translation and terms used for middle school students were appropriate. While the VASI questionnaire is based on 8 fundamental aspects of scientific inquiry from the NSES, it consists of only seven items, as the questionnaire integrates certain concepts from the NSES into a single item. A detailed description of the questionnaire's contents is shown in **Table 1**. The VASI questionnaire is open-ended, and some of its items contain one or two sub-questions. On average, students took between 20 and 30 minutes to complete the instrument.

Data Analysis

Responses were classified into 'informed', 'mixed', and 'naïve' according to rubric for scoring the VASI Questionnaire (Lederman et al., 2014). Students' responses to each question were classified according to the examples and explanations that were provided in the rubric. Generally, if the responses were empirical or contradicted a certain feature's accepted views, then they were classified as 'naïve'. A naïve response may look like one of the following examples: "there is only one scientific method," or "similar procedures will always lead to the same results." By contrast, responses were classified as 'informed' when they were relative, constructive (Deng et al., 2011), or corresponded with a targeted aspect of scientific inquiry. An informed response may look like one of the following examples: "investigations can follow different methods, such as research, observation, or experimentation," or "human factors may cause different interpretations of similar data, which can lead to different results." The mixed classification designated responses that partially corresponded with an informed view. When

Table 1. Contents of the VASI questionnaire

Question number	Sub question	Target aspects on VASI questionnaire	Aspects in NSES
1	1a 1b 1c	Scientific investigations can follow different methods	(2) There is no single set of steps followed in all investigations (i.e. there is no single scientific method)
2		A scientific investigation should begin with a question, not necessarily a hypothesis	(1) Scientific investigations all begin with a question and do not necessarily test a hypothesis
3	3a	All scientists performing the same procedures may not get the same results	(4) All scientists performing the same procedures may not get the same results
	3b	Procedures of investigations can influence results	(5) Inquiry procedures can influence results
4		Data is not the same as scientific evidence	(7) Scientific data is not the same as scientific evidence
5		Question drives the process	(3) Inquiry procedures are guided by the question asked
6		Conclusions should be consistent with data collected	(6) Research conclusions must be consistent with the data collected
7	7a 7b	Explanations must be based on data and existing scientific knowledge	(8) Explanations are developed from a combination of collected data and what is already known.

an example or description in the rubric was unclear, the researchers discussed them for refinement and clarified their categorization.

Two independent researchers coded samples of student responses to establish inter-rater reliability, and 400 independent judgements about responses were checked for agreement. Inter-rater reliability was computed using Cohen's kappa. The inter-rater reliability between the two raters was K = 0.93. After calculating inter-rater reliability, disagreements were resolved through further discussion. Following this, one researcher continued to classify the responses as naïve, mixed, and informed. If responses were unclear or problematic, they were discussed by the researchers to reach a consensus.

RESULTS

Statistics for the students' responses to the VASI questionnaire are displayed in **Table 2**. As shown in the table, Korean middle school students generally had mixed (45.0 %) or naïve (44.0 %) views about scientific inquiry. Most specifically, most of the students had informed views for "all scientists performing the same procedures may not get the same results" (64.2 %) and majority of the students had naïve views for "scientific investigations can follow different methods" (97. 2 %) and "explanations must be based on data and existing scientific knowledge" (77.0 %).

Korean middle school students' responses differed from each aspect of scientific inquiry, and these responses were analysed by questions.

Table 2. Statistics for the students' views on the VASI questionnaire

Question number	Aspects	Informed	Mixed	Naïve	Unclear
					(N=282) (%)
1a, 1b and 1c	Scientific investigations can follow different methods	0	2.8	97.2	0
2	A scientific investigation should begin with a question, not necessarily a hypothesis	4.6	63.0	32.0	0.4
3a	All scientists performing the same procedures may not get the same results	64.2	17.4	18.1	0.3
3b	Procedures of investigations can influence results	19.1	63.5	14.2	3.2
4	Data is not the same as scientific evidence	7.1	63.1	29.4	0
5	Question drives the process	32.6	54.3	12.8	0.3
6	Conclusions should be consistent with data collected	43.6	32.0	24.1	0.3
7a, 7b	Explanations must be based on data and existing scientific knowledge	2.8	20.0	77.0	0.2

Question 1

Question 1 explored the idea that there is no single scientific method or process. As such, the question was divided into three sub-questions: question 1a, which was designed to facilitate an understanding of the word 'scientific', question 1b, which was designed to facilitate an understanding of the word 'experiment', and question 1c, which was designed to facilitate an understanding of the various methods of investigation. As an example, after reading a short story about an individual's inquiry about a bird, a student would answer these questions to explain how the activity was scientific and how it was an experiment. A student would also answer whether scientists could follow different methods as they conducted their inquiry. If a student answered "no," they would need to explain why scientists would follow only one method. If a student answered "yes", they would need to list the multiple scientific methods that scientists could employ and explain the differences between them. In this study, while the majority of students had a naïve view (96.8 %) in response to question 1, some held a mixed view (3.2 %).

To put it more specifically, question 1a asked students to judge whether or not the presented case was scientific. The word scientific means to understand nature through observation or experimentation. Furthermore, it explores the phenomenon of nature logically, rationally, and objectively. Therefore, the presented case was a scientific investigation. While some students disagreed with the idea that the presented case was scientific (14.2%), most agreed (78.0%). The case was determined to be scientific due to observations (24.1%), scientific inquiry processes (e.g., observations as data collection and data collection for the purposes of drawing conclusions) (11.4%), the exploration of curious questions (7.1%), and the exploration of objectivity or logicality (1.1 %).

Question 1b asked students to determine if the case was an experiment. An Experiment is a practical activity that results in the collection of data to test hypotheses that are based on control variables (Schwartz et al., 2008). Therefore, the presented case was not an experiment. While nearly half of the students (57.3%) judged that the case was an experiment, 38.5% of the students disagreed. The students who responded that the case was an experiment because an observation was performed (16.8%), data were collected (12.2 %), a conclusion was drawn (8.4%), or because an exploration process from problem recognition to conclusion went through (7.3%). The students who responded that the case was not an experiment responded because an observation was performed (16.0%), data were collected (5.7%), or because they themselves were not the ones who performed it (5.0%). Some students responded that the case was not an experiment because a discovery was made, a tool was not used, or because hypothesis was not established. Only 2.7% of the students responded that this case was not an experiment because no variable was controlled or manipulated.

Question 1c asked students if scientists were able to use multiple methods or only a single method during scientific inquiry. While 70.2% of the students responded that multiple methods cloud be used, 10.3% of the students responded that only one method could be used during scientific inquiry. Out of the students who responded that multiple methods cloud be used for scientific inquiry, 48.2% of the students described two or more valid inquiry methods such as experiment, observation, and survey, while 22.0% of the students listed science process skills such as observation, reasoning, measurement, and classification as examples of various methods of scientific inquiry. The students who responded that an inquiry cloud be performed with only a single method mentioned observation, experiment, survey, animal anatomy, and reasoning.

Question 2

Question 2 explored the idea that scientific inquiry should start with a question and not necessarily a hypothesis. In response to the question about whether scientific investigations should start with a scientific question, students were required to select "yes" or "no" and to explain the reasoning behind their answers. At least 4.6% of students' responses were classified as informed because they understood that scientific questions were the primary factors that led to scientific exploration. On the other hand, 63.0% of the students' responses were classified as mixed because they understood the need for questions as the starting point of a scientific investigation but were unable to logically explain the reason behind their answers. Finally, 32.0% of the students' responses were classified as naïve because they did not believe that questions were important for scientific inquiry.

In response to the question, "should scientific investigation start with a question?" students who answered "no" did so because they believed that scientific investigations started with curiosity (11.1%), scientific investigations started with daily life experiences or trivial activities (8.5%), or scientific investigations started with minor questions rather than scientific questions (8.5%). Finally, at least 3.9% of the students responded that questions were not necessary to start a scientific investigation.

Question 3a

Question 3a assessed the idea that scientists who perform the same procedures may not get the same results. Because scientists' experiences, expectations, prior knowledge, and theoretical beliefs can affect the interpretation process, their results may vary (Lederman et al., 2002). Students were required to answer the question, "when scientists use the same procedures to gather data, are their conclusions the same?" and explain their reasons for choosing their answers. At least 64.2% of the students' responses were classified as informed because they responded that different conclusions and interpretations could be drawn regardless of whether or not multiple scientists carried out the same investigation processes with the same problems, 17.3% of the students' responses were classified as mixed because they responded that different conclusions could be drawn due to imperfect experimental circumstances, such as experimental error, and 18.1% of the students' responses were classified as naïve because they responded that the conclusions would always be the same if the exploratory processes were similar.

Question 3b

This question was given to verify whether students understood that different results could be obtained through different exploratory procedures. Students were required to answer the question, "when scientists' procedures for gathering data are not same, are their conclusions the same?" and explain their reasons for choosing their answers. At least 19.1% of the students' responses were classified as informed because they responded that different conclusions could be drawn from different data sets, 63.5% of the student's responses were classified as mixed because they responded that different conclusions could be drawn from different interpretations, and 14.2% of the students' responses were classified as naïve because they responded that only one conclusion could be drawn regardless of the procedure.

Question 4

Question 4 explored the differences between data and scientific evidence. While data are information that have been collected during scientific investigations, evidence, which is the basis for conclusions, is the result of interpretations or analyses of data (Schwartz et al., 2008). Students were required to select "yes" or "no" in response to the question that asked if data and evidence were the same and were then asked to explain the reasons for their answers. At least 7.1% of the students' responses were classified as informed because they logically explained that data and evidence were different, 63.1% of the students' responses were classified as mixed because they understood that data and evidence were different but were unable to explain their differences, and 29.4% of the students' responses were classified as naïve because they responded that data and evidence were the same.

Question 5

Question 5 addressed the idea that questions lead to procedures. After comparing two team's test processes, students were asked to select and explain which process they thought was superior. The represented processes were as follows: scientists saw a flat tire and asked, 'which company's tire is the easiest to puncture?' While team A rolled several companies' tires over the three types of surfaces, team B rolled only one of the company's tires over the three types of surfaces. At least 32.6% of the students' responses were classified as informed because they were able to verify the exploratory question and choose the appropriate experimental design, 54.3% of the students' responses were classified as mixed because they chose the appropriate experimental design but were unable to provide a logical explanation for their choice, and 12.8% of the students' responses were classified as naïve because they were unable to choose the appropriate experimental design.

A closer look at the students' responses reveals that certain criteria were used to determine if the students understood the suitability of the experimental procedure. While 32.6% of the students examined the exploratory question in order to choose an appropriate experimental process, 67.1% of the students did not consider the question carefully. Students who showed mixed responses claimed that testing various tires was good regardless of the exploratory question because the collection of additional data was beneficial (21.7%), testing various tires was good for comparison (18.1%), or testing various tires provided more accurate results (14.5 %). Finally, at least 12.8% of the students selected team B. In this group, 4% of the students responded that testing the tires of a single company was good regardless of the exploratory question because the testing of single company's tires was more accurate, concentrating on one company was good because the data it produced were less complicated, or conclusions could be more easily drawn from the experimental design when it only included a single company.

Question 6

This question was given to verify if students understood that conclusions must be consistent with data. Students were required to select the proper conclusion (e.g., "The more minutes of light, the more plant growth," "The less minutes of light, the more plant growth," and "Growth of the plant and light are not related") in response to the table about plant growth below and were then asked to explain the reason for choosing their answer. The presented table was presented in **Table 3**.

At least 43.6% of the students' responses were classified as informed because they drew the correct conclusion by understanding the trend of data, 32.0% of the students' responses were classified as mixed because they drew the correct conclusion but their processes for drawing those conclusions were illogical or they did not understand the trend of data, and 24.1% of the students' responses were classified as naïve because they were unable to draw the right conclusion.

Table 3. Presented table in the question 6 (Gaigher et al., 2014)

Minutes of light per each day (minute)	Height of plants' growth per week (cm)
0	25
5	20
10	15
15	5
20	10
25	0

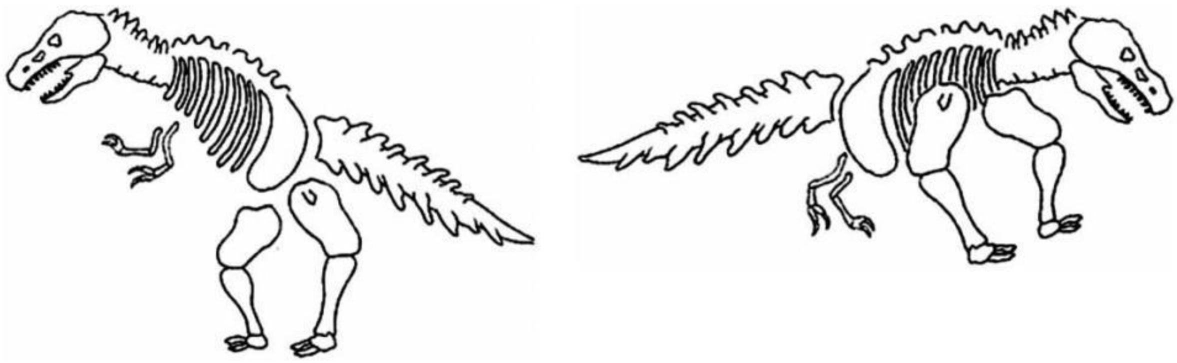

Figure 1. The picture of a dinosaur's bones

In response to the mixed and naïve responses, which did not make the correct conclusions in response to the given data, 13.5% of the students used their own knowledge to draw a conclusion while ignoring the presented data. In addition, some of the students were unable to correctly recognize the data's trends. At least 11.7% of the students failed to focus on the entire trend of data because they believed that the presented data lacked a trend when a single data point was on outlier on the traditional trend set. On the other hand, 8.2% of the students verified if the data were measured regularly or irregularly with the belief that only regular increases or decreases in the numbers could represent a trend. While some of the students drew a conclusion by verifying only the first and final data points, others drew a conclusion by verifying only a single part of the presented data.

Question 7

Question 7 assessed the idea that explanations should be based on data and existing knowledge. Students were required to answer why scientists agreed that the picture of a dinosaur's bones (See **Figure 1**) was appropriate and to then write about the types of information that scientists used to draw and explain their conclusions. The picture of the bones is presented below.

Table 4. Examples of the responses

Question number	Category	Responses
1	Informed	No response was classified as Informed
	Mixed	Student 335: 1a) This is scientific. He was asked a question that was related to nature, and he tried to answer the question by explaining nature. 1b) This is not an experiment. Many experiments were not carried out. Research was conducted as result of general knowledge and curiosity. 1c) There are several ways to perform scientific inquiry, such as research and experimentation.
	Naïve	Student 374: 1c) Scientists can only use experiments for scientific inquiry, as two or more methods can produce different results. Student 274: 1a) This is not scientific. He did not investigate every kind of bird. Exceptions may be present. 1b) This is an experiment. Even if the results do not fit the scientific facts, he tried to identify new information through observation. 1c) Observation, experiment, experience can be used for scientific inquiry.
2	Informed	Student 318: Yes, To question with curiosity helps to start inquiry. Student 335: Yes, Question is the first process of inquiry. Questions are also the basis for inquiry. Scientific inquiry cannot be achieved without a question.
	Mixed	Student 337: No, a question may arise during the scientific inquiry. Student 442 No, No, a trivial activity that is experienced during everyday life can lead to scientific inquiry.
	Naïve	Student 214: No, inquiry can be started without questions. Student 447: No, inquiry should begin with observation or collecting data first, not from asking question. If you start from questions, it will take a lot of time.
3a	Informed	Student 204: No, because each person interprets data differently. Student 217. No, people may have different opinions.

Table 4 (continued). Examples of the responses

Question number	Category	Responses
	Mixed	Student 219: No, there may also be small errors between experiments that result in different conclusions. student 343: No. Though the procedure was same, there is no guarantee that the same data was collected.
	Naïve	Student 397: Yes. If data is collected correctly, scientists' conclusion will be same. Student 279: Yes. If the process of collecting data was the same, the results will be the same.
3b	Informed	Student 217: No, because collected data is different from each other.
	Mixed	Student 211: No, because viewpoints on interpretation are different. Student 243 No, due to differences in opinion and experiences of all the people involved.
	Naïve	Student 277: Yes, there is only one answer to the question. Though scientists performed different procedures, their data will be exactly the same. Their conclusions will also be the same.
4	Informed	Student 335: No, data make up the largest part of evidence. Data are all the information about a certain topic, but evidence is information that is selected from data to support what researchers aim to prove. Student 412: No, data are information about any facts or phenomenon. Evidence supports a conclusion. When evidence fails to support a conclusion, it is merely part of the data that does not provide evidence.
	Mixed	Student 395: No, while data are just information, evidence is related to the claim. Student 413 No, data are facts that will be discovered through research. Evidence is what people believe because of a certain fact.

Table 4 (continued). Examples of the responses

Question number	Category	Responses
	Naïve	Student 425: Yes, data and evidence hint at the solution to a problem. Student 429: Yes, data and evidence are similar. Data may be evidence and vice versa.
5	Informed	Student 209: Team A. The question asks which brand of tire is the most likely to go flat.
	Mixed	Student 214: Team A. It is more accurate to test several tires than a single tire. Student 226: Team A. This method can provide comparisons between the companies and acquire more data.
	Naïve	Student 218: Team B. Team B is testing one tire on three types of roads. It can achieve more accurate results. Student 225: Team B. It is more efficient to use a single tire from a single company.
6	Informed	Student 206: 2. According to the table, the greater the amount of sunlight, the shorter the length of time that it will take for the plant to grow. Student 209: 2. Frankly, this is beyond common sense. However, according to the data, the more light, the shorter the length of time that it will take for the plant to grow.
	Mixed	Student 365: 2. The table reveals that the plant does not grow for up to 15 minutes, until suddenly, its length begins to increase. Student 396: The growth rate would neither increase nor decrease regularly. Student 433: 3. The plants that received sunlight for 25 minutes grew 0. The plants that received no sunlight grew 25 cm.

Table 4 (continued). Examples of the responses

Question number	Category	Responses
	Naïve	Student 280: 1. Because we were taught this way. Student 362: 3. It will be associated with the sun, but oxygen and carbon dioxide may also be relevant.
7	Informed	Student 225 7a) The bones and joints in Figure 1 fit well. People think that dinosaur bones look this way because they are similar to current dinosaurs. 7b) A picture of dinosaurs' fossils and the materials that make up a dinosaur's fossils. Student 311 7a) Most dinosaurs' back legs are thicker than their forearms. The front legs should be thick to sustain the body. 7b) Previous research has revealed similar findings..
	Mixed	Student 353 7a) In figure 1, a dinosaur is standing in a stable posture because of its short forearms and thick hind legs. Light and sharp forelegs are necessary for dinosaur to hunt prey. 7b) Background of age, condition, knowledge, testimony of others, people's belief. Student 475 7a) The principle that all animals are able to stand is similar to the image that is presented in figure 1. The dinosaur in figure 1 fits well between bones. 7b) Experiment results
	Naïve	Student 444 7a) The leg bones and ribs cannot be connected like that image in figure 1. 7b) Collecting data, doing an experiment, and investigation. Student 454 7a) Similar to human beings, the dinosaur in figure 1 is standing on both feet. Standing on both feet allows it to run faster. 7b) Accurate information with high reliability.

While a majority of the students' responses to the picture were classified as naïve (77.0%), 20.0% were classified as mixed responses, and only 2.8% were classified as informed responses.

Question 7a asked students to describe the reasons that scientists agreed that the picture was an appropriate arrangement of dinosaur bones. At least 50.5% of the students described the function of the larger hind legs for the reason, 21.8 % of the students made references and comparisons to existing dinosaur shapes, and 4.5 % of the students referred to the fittings of the joints.

Question 7b required generalized information, which scientists used to explain their conclusions. Although only 3.5% of the students referred to existing knowledge and scientific theories that have already been derived in universal facts or found in related books, papers, or encyclopedias. Most of the students described the internet, credible evidence, specific information, or experimental results as the sources of scientists' conclusions.

Detailed student responses for each question (question 1 ~ question 7) are provided in **Table 4**.

DISCUSSION

In this study, Korean middle school students' views about scientific inquiry were explored. The most understood view of scientific inquiry was explored in question 3a, that the same process may not get same results. This was demonstrated by an informed response of 64%. By contrast, most Taiwanese students held naïve views about this aspect (Antink-Meyer, 2016).

In addition, question 6, which addressed the idea that conclusions should be consistent with data and knowledge, and question 5, which addressed the idea that questions drive scientific processes, were well understood. These findings are consistent with previous studies by Gaiher et al. (2014), which tested South African high school students, and Antink-Meyer (2016), which tested Taiwanese secondary school students.

The poorest understood aspect of inquiry was established in question 1, which addressed the idea that scientific investigations can follow different methods. For this question, 97.2% of the students' responses were classified as naïve, as the majority of students were unable to explain the meanings of the words experiment and scientific. While U.S. and South African students also exhibited poor understanding of this idea aspect (Gaiher et al., 2014; Senler, 2015), Turkish students proved to hold more informed views about this aspect (Senler, 2015). Senler (2015) argued that Turkish students had more time to observe teachers' demonstrations than to perform experiments of their own, which may have led them to conclude that descriptive studies are also scientific. Lederman et al. (2014) argued that the idea that only one scientific method exists is due to classical experimental designs.

Korean students often take part in hands-on scientific activities and experiments during their elementary school science classes. While these hands-on activities do not involve the testing of multiple variables, they are commonly called experiments (McComas, 1998). There is little opportunity for students to control or test variables themselves. Furthermore, the ratio of experiment-centered classes has been reported to be less than 10% in Korean secondary schools (Choi & Seo, 2012). As a result of these factors, students are often unable to adequately understand the meaning of the word experiment and thus regard experiments as the only method for conducting scientific inquiry. Fortunately, a diverse number of methods for performing scientific inquiry (e g. devising, descriptive investigating, etc.) have been illustrated in recent Korean science textbooks. Most of the students in this study listed scientific process skills as components of scientific method and judged scientific inquiry by considering these skills. In Korean science textbooks, scientific process skills are explicitly explained with examples (Lim et al., 2007). The independent inquiry units may influence students to believe that inquiry means just scientific process skill.

In regards to the idea addressed by question 7, which asked if "explanations must be based on data and existing scientific knowledge," while 77% of the students responded with naïve views, most students did not consider existing knowledge as they drew their conclusions. By comparison, most U.S. students have held either informed or mixed views about this aspect (Senler, 2015).

For question 4, students were either confused by, misunderstood, or had trouble distinguishing between data and evidence. This implies that students failed to understand the differences between inquiry results and inference through the interpretation of data (Han et al., 2012). In Korea, most classes end lessons by announcing students' experimental results or by arriving at conclusions that are based solely on their teachers' opinions (Yang et al., 2006). This can prevent students from fully understanding that they should interpret data while looking for evidence and draw conclusions by using evidence.

For question 3, interestingly, students believed that scientists were influenced by subjectivity and so could arrive at different conclusions for the same procedures. These findings are consistent with a previous study conducted with South African students (Dudu & Vhurumuku, 2011).

Overall, Korean middle school students lacked a clear understanding of the aspect of scientific inquiry. Although scientific inquiry was highlighted in Korea's scientific curriculum and reflected in the country's science classes, the scientific inquiry that students experience in class was designed to answer questions that are presented in textbooks or to follow the directions written on the textbooks (Kwak, 2011). When students experience inquiry in this way, they are less likely to establish contemporary views about scientific inquiry. Veal and Allan (2013) noted that cookbook laboratory activities, wherein students simply follow a series of instructions, are insufficient at establishing alternatives to inquiry.

Scientific inquiry should be considered during the design and development of scientific curriculum. Senler (2015) reported that U.S students' views about scientific inquiry were remarkably more informed than the views of Turkish students because their curriculum focused on scientific inquiry. It is therefore necessary to discuss how to reflect scientific inquiry within textbooks and during instruction. Researchers have emphasized that scientific inquiry needs to be taught explicitly and reflectively during instruction of the sciences rather than expected to be learned by doing science (Liu & Lederman, 2007; Lederman et al., 2013). However, teaching each scientific process skill independently will not guarantee students the ability to recall that information when they need it (Hodson, 1992). While conducting scientific inquiry can be a starting point for students, they also need to discuss the reasons behind the design of scientific inquiry (Lederman et al., 2013). In addition, because students' beliefs about scientific inquiry are not easily changed, knowledge about the nature of scientific inquiry should continue to be emphasized through systematic planning (Lederman, 2007).

Because teachers can also find it difficult to understand scientific inquiry (Senler, 2015), it is essential to develop their knowledge about the NOSI. Recently, Korean teaching education in the sciences has emphasized the NOS and NOSI. Regardless, there are currently not enough professional development programs or seminars to facilitate the instruction of scientific inquiry. As a result, a variety of methods to improve knowledge about inquiry, such as reading and mentoring, have been proposed (Abd-El-Khalick & Lederman, 2000). To improve teachers' and students' knowledge of NOSI, more research should be undertaken to gain insight into their views about the process.

CONCLUSION

In general, Korean middle school students held mixed or naïve views about scientific inquiry. While they understood the aspects that "all scientists performing the same procedures may not get the same results" and that "conclusions should be consistent with the data that have been collected," they did not fully understand the aspects that "questions drive processes", "the procedures of an investigation can influence its results.", "data is not the same as scientific evidence", and that "a scientific investigation should begin with a question and not necessarily a hypothesis."

Looking at the students' responses to these weak aspect of the scientific inquiry in more detail, when students tried to identify the correct process for an investigation, rather than consider the inquiry that was present, they selected processes that looked as if they would more easily facilitate or result in additional data collection. Also the analyses of students' responses revealed that students did not understand how to control variables. As they were unaware of the importance of the question, a majority of the students responded that scientific investigation could start from daily life experiences or trivial activities, and some even responded that scientific investigations did not require hypotheses or scientific questions.

In particular, the poorest understood aspects of scientific inquiry were that "scientific investigations can follow different methods" and that "explanations must be based on data and existing scientific knowledge." Most students did not comprehend the meanings of the words scientific and experiment. In addition, they paid little attention to the diversity of scientific methods.

According to the aforementioned results, explicit and reflective instruction is necessary to the development of students' knowledge about scientific inquiry. In addition, teacher insight into the modern epistemological perspective of scientific inquiry should be promoted through specialized training. Revisions to the current curriculum so that it highlights the educational goals and contents of scientific inquiry should also be established.

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