Elementary School Students' Understanding of Nature of Scientific Inquiry: A Preliminary Results and Proposed Practical Framework

Sasivimol PREMTHAISONG[a], Wacharaporn KHAOKHAJORN[a,b], Pawat CHAIPIDECH[a] & Niwat SRISAWASDI[a*]

[a]*Faculty of Education, Khon Kaen University, Thailand*
[b]*Faculty of Education, Sakon Nakhon Rajabhat University, Thailand* *niwsri@kku.ac.th

Abstract: With the benefits of the inquiry-based learning environment provides opportunities for students to enquire knowledge in a procedural way by using technology in science classrooms. Similarly, the nature of scientific inquiry (NOSI) is the fundamental understanding of scientific inquiry in which students should know how to do practice to obtain scientific knowledge. The aim of this study was to investigate the understanding about the nature of scientific inquiry in elementary students. A total of 22 participants were involved in this study. A View about Scientific Inquiry for Elementary (VASI-E) questionnaire was administered to capture their understanding of NOSI. Data were analyzed by content analysis and inter-rater reliability techniques. The research results showed that the elementary school students mostly lack of a multiple method aspect regarding understanding about the nature of scientific inquiry. Consequently, a three-layers competency-based inquiry learning activities with supports of digital technology has been proposed as innovative instructional intervention to improve elementary school students' understanding of NOSI, and an illustrative idea is also presented in this paper.

Keywords: Nature of scientific inquiry, inquiry-based learning, technology

1. Introduction

In science education, inquiry is one of the few influential themes that are embedded in school curriculum around the world (Abd-El-Khalick et al., 2004). Scientific inquiry (SI) has been referred to combining knowledge of science topics, creativity, and critical thinking with general science process abilities to investigate nature. (Lederman et al., 2014). Roberts (2008) stated that one of the objectives of science education has been and still is to assist students in forming informed opinions about SI. SI and nature of science (NOS) are often used as synonymous terms. Although SI and NOS are not independent from one another, there is a difference between the two. NOS embodies what makes science different from other disciplines such as history or religion. In addition, NOS refers to the characteristics of scientific knowledge that are necessarily derived from how the knowledge is developed (Lederman, 2006). SI is the process of how scientists do their work and how the resulting scientific knowledge is generated and accepted. This contrast is further supported by the Next Generation Science Standards (NGSS; Achieve, Inc., 2013) which distinguishes between NOS and scientific practices.

From the vision of the National Science Education Standards (National Research Council, 1996), students are required to be able to propose scientific questions and then plan and execute investigations that will provide the data needed to reach conclusions for the stated questions. The Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993) are less motivated in that they do not encourage all students to be able to design and conduct investigations. Furthermore, this situation is found in the Thailand curricula as well. Lederman et al. (2021) conducted baseline research regarding NOSI, the findings illustrate that most of 117 in 12th grade students held naïve or mixed views of six of the eight aspects of NOSI examined in this study. It implied that Thai students failed to express an informed understanding about SI. At the same time, even the research indicated that elementary students can develop an informed understanding of many aspects of inquiry when provided with the appropriate educational circumstances, there is remain significantly less research on the topic of students' understanding of SI than on their performing of inquiry to learn science concepts (Lederman et al., 2013).

Due to the lack of the research which investigates students' understanding about SI, especially in Thailand context. This study focuses on investigating the understanding of NOSI in elementary school students who are beginners of learning science following the basic education core curriculum. Furthermore, the researchers proposed a learning module integrated with digital technologies to enhance their understanding of NOSI. In particular, our research question is what are elementary students' views about scientific inquiry?. In addition, the researchers proposed a practical framework of elementary science learning module for promoting their NOSI with the support of digital learning environments at the end of this paper.

2. Literature Review

2.1 The View About Scientific Inquiry (VASI)

The Views about Scientific Inquiry (VASI) is a questionnaire that has been used to probe not only the student's action while engaged in inquiry activities, but also test the understanding of scientific inquiry (Lederman et al., 2014). The VASI questionnaire was contributed to students in year 7 in a cross- sectional design involving 18 countries as the international collaboration, and a sample size of the study was 2,634 students (Lederman et al., 2019). The findings are intended to investigate assumptions about how the students learn about scientific inquiry in further detail and to provide science teachers and science educators more effective tools for evaluating students' comprehension of key elements of scientific inquiry. The VASI questionnaire is based on the following propositions describing aspects of scientific inquiry about which there is general agreement, and that are both possible and relevant for school children to learn. The researchers recommend the original article by Lederman et al. (2014) for a more description of these eight aspects and their justifications regarding the view about scientific inquiry:

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

Recently, international collaborative research was conducted in 32 countries including Thailand in order to investigate students' views about scientific inquiry in high school level (Lederman et al., 2021). The result illustrated that Thai students held naïve or mixed views of six of the eight aspects of NOSI examined in this study. For the most informed aspect, 47.86% and 41.03% of students exhibited informed views on procedures are guided by the question asked and conclusions consistent with data collected. The most mixed and naïve aspects of NOSI were 67.52% and 69.23% on Procedures influence results and data does not equal evidence, respectively. This implied that it seems Thai students failed to express a qualified view of NOSI.

2.2 Nature of Scientific Inquiry (NOSI) in School Science Education

The fundamental understanding of the nature of scientific inquiry (NOSI) is the comprehension of systematic investigation. In science classroom, Inquiry is typically taught by design the task which allows students conduct investigations or by the emersion of learners in authentic contexts (Sadler, Burgin, McKinney, & Ponjuane, 2010). This is assumed to develop students' knowledge about SI. Theproblematic nature of the assumption can be illuminated by a simple example: students are often asked to control for variables when conducting investigations but may not necessarily have an informed conception of the purpose of doing so, as it relates to the design. Students can participate in inquiry "experiences" but unless instruction explicitly addresses common characteristics of SI, students are more likely to continue to hold naïve conceptions. As Metz (2004) summarizes, "the small research literature examining the epistemic outcomes of inquiry-based classroom instruction indicates that simply engaging students in 'inquiry' is insufficient to bring about these desired changes".

In Thailand context, science teachers are introduced to teaching science under the constructivist view of learning and, accordingly, the main teaching approaches are inquiry-based learning, project- based and problem-based learning. However, researchers have indicated that Thai science teachers place too much emphasis on memorization and assessment driven learning with a focus on fragmented knowledge, rather than scientific inquiry and core concepts (Atagi, 2002; Ketsing & Roadrangka, 2010). There are some difficulties in implementing these teaching approaches. Ketsing and Roadrangka (2010) indicated that the major difficulty is teachers' misconception of inquiry. Science teachers hold a partial understanding of the inquiry concept and do not realize that inquiry is a method for investigating natural phenomena and that scientists use it to gain knowledge based on evidence. Most of the activities that teachers promote rely on a teacher-directed approach. Further, while some teachers are aware of the value and importance of inquiry, in practice, they reject it for a variety of reasons, such as time constraints, the current evaluation policies and values, and cultural and political influences (Faikhamta & Ladachart, 2016).

3. Method

3.1 Participants

The participants in this study consisted of 22 fourth- and fifth-grade elementary school students at a university-based demonstration school located in the northeastern part of Thailand. Their age range is between 10-11 years old. They have experience in learning science following the basic education curriculum in Thailand for four years.

3.2 Instrument

In order to investigate the students' nature of scientific inquiry, the view of scientific inquiry questionnaire (VASI) was employed (Lederman, 2014). The View about Scientific Inquiry for Elementary (VASI-E) questionnaire is a later version of VASI for elementary school science developed by (Lederman et al., in press) was translated from English into Thai by the first author and independently back translated from Thai into English by the second author. This instrument related to the international project which explored the baseline of learner's understanding of nature of scientific inquiry (Lederman, 2021). According to the study, the content validity is confirmed by experts which addressing targeted aspects of SI with 100% agreement. The experts also ensure that all aspect of scientific inquiry is addressed. For construct validity, it can be established if individual evaluators believed to differ in understanding respond differently on a targeted assessment. Sample items of the questionnaire are as follows.

- ⋆ There was a woman who toured the globe in search of birds. She saw that the beaks of birds came in a wide variety. Some beaks were short and small. Some beaks were long and thin. Some were very big and thick. She also saw that birds consumed a wide variety of foods. She asked, "Is there a connection between the shape and size of birds' beaks and the types of food they ate?" So, then she went out and observed many more birds to try to answer her question. A) Do you think she was working like a scientist? B) Why or why not?

3.3 Students in two groups wanted to know if different crayon colors melted more quickly than others.

Group A put 3 different colored crayons under one type of hot light. Group B put red crayons under 3 different types of hot lights. Which group has the better plan? Explain why. Data Collection and Analysis

Each elementary school student was given a VASI-E questionnaire to complete in 60 minutes via the exam online platform. After administering the VASI questionnaire, the results were coded by the primary contact person and science educator colleagues. Each student was given a code of; Informed, Mixed, or Naïve for each aspect of NOSI. In case of elementary school students reply to a response consistent across the complete questionnaire that is completely congruous with the participant response for a given aspect of NOSI they are labeled as 'informed'. If they give a result that is either only partially correct, or if they didn't answer all parts to the question, a score of 'mixed' is given. Lastly, a response that is contradictory to accepted views of an aspect of NOSI and provides no evidence related to accepted views of the specific aspect of NOSI under survey is scored as 'naïve'.

4. Result

4.1 Percentage of Elementary School Students' NOSI

The responses from 22 elementary school student participants obtained by VASI-E questionnaires is concluded in Table 1.

Table 1. *Percentage of elementary school students with naïve, mixed, and informed responses.*

Aspect	Aspects of scientific inquiry	% Naïve	% Mixed	% Informed
1	Begin with a question	9.09	45.45	45.45
2	Multiple methods	22.73	54.55	22.73
5	Conclusions must be consistent with data collected	13.6	31.8	54.5
6	Inquiry procedures are guided by the question asked	13.6	59.1	27.3
8	Explanations are developed from collected data and prior knowledge	13.6	13.6	54.5

All students' responses to the VASI questionnaire were scored by three researchers. This result of elementary school students demonstrated that the highest percentage of informed aspects were *conclusions consistent with data*, *explanation from data and prior knowledge*, *begin with a question*, *inquiry procedures are guided by the question asked* and *multiple methods*, respectively. One possible reason for these informed views is that students obtained opportunities from teachers in this region to develop a conclusion based on the data collected.

4.2 Some General Trends of Elementary School Students' NOSI

Aspects of the elementary school students of understanding about scientific inquiry were ranked from less to more informed in an overview of their characteristics. The top three informed factors in the fourth grade were:

Aspect 5: *Conclusions must be consistent with data collected* (54.5%)
Aspect 8: *Explanations are developed from collected data and prior knowledge* (54.5%)
Aspect 1: *Begin with a question* (45.45%)

In contrast, the most naïve views in the fourth-grade sample are found in:
Aspect 2: Multiple method (22.73%)

Aspect 6, that *inquiry procedures are guided by the question asked* exhibited mostly mixed answers with 59.1%.

4.3 Examples of How Students Responded to the VASI-E questionnaire

Here, researchers indicated a few examples of elementary school students in fourth- and fifth-grade students and various aspects of scientific inquiry that responded to the VASI. Researchers follow the order in which the five aspects appear on the VASI-Elementary questionnaire.

4.3.1 Aspect 1, Starts with a Question

The first aspect of the VASI-Elementary questionnaire in questions 4a) and 4b) is about a picture of a different ball. Here is student#1 in fourth grade. She answered in question 4a) about if a friend picked up the ball and bounced it, would they do a science investigation:

"No, because it's a play. He just plays the ball because it's don't have any question before he plays the ball."

And she continues her answer in question 4b, which asks if this particular investigation is an experiment. After that, she answers this question by writing two questions that are shown below:

"1. How high can each of the ball bounce with the same force? 2. Does the weight and size of each ball affect its bounce?"

Moreover, the VASI-Elementary questionnaire in question 1a) related to aspect 1. Here is student#1 in fifth grade.

"Yes, she works as a scientist because she observes birds and she knows the bird how to eat food, each bird has a different mouth."

This was also estimated as an inform answer according to the criteria for the VASI-Elementary scoring. However, it requires more in-depth and demonstrates how research is pragmatic in nature, with research topics frequently changing as new information is discovered.

4.3.2 Aspect 2, Multiple Methods

An example of an informed answer related to aspect 2 was given by student#2 in fifth-grade to questions 1a and 1b on the VASI-Elementary questionnaire, concerning if a scientific investigation always begins with a question about the myth of a single scientific method, approached through an example of observing birds' beaks and eating habits where students are asked if this is a scientific investigation:

1a) "This woman is a scientist because she was observant and tried to find her own answers."

1b) “This woman is not performing a science experiment because she didn't feed each bird, she only surveyed and compared them.”

According to the previous answer stated concerning the use of this crucial idea, the term "experiment" does not appear to have any specific significance to this student other than that it is equivalent to "observing".

4.3.3 Aspect 5 and 8, Conclusions consistent with data and Explanations are developed from data and what is already know

Item two on the VASI-Elementary seeks to create a context to tested aspect 5 and 8. It related to the fossilized bones of dinosaur.

4a)“Scientists know it because there are dinosaur bones and fossil left on it. Moreover, they have surveyed to find more information. However, no scientist has ever seen a real dinosaur. But they also knew that dinosaurs existed. Scientists try to compare this bone with another animal, but they cannot find other animals that have the same size as this bone. Therefore, scientists assumed that This bone was a dinosaur bone.”

4b) “Scientists think dinosaur bones are large and many species. Because the bone size is larger than other animals by surveying and comparing the data.”

And an even more answer is given by student#3 in fifth grade:

4a) “scientists know from fossils of dinosaurs that even the dinosaur doesn’t exist anymore, but the bone of the dinosaur existed in some old cave that has a foreign matter or can be a dinosaur painting on it and drawn by people that exist in that era.”

4b) “I think it's because scientists used the bones of large dinosaurs compare with normal animal bones to see similarities. Another reason about the big size of the bones and how many bones were found at the place of the scientists or scientists trying to arrange the bone to turn into a dinosaur figure and observed the sharp teeth. Or maybe taken to examine the gene of the bone to see what it is.”

4.3.4 Aspect 6, Inquiry procedures are guided by the question asked

Item three tested aspect 6 of understanding inquiry by posing a question about which testing group of candles has a better plan from the experiment? This is an example of an informed response from student 4 fifth grade on elementary school students:

“Group 1 had the best idea of experimenting because group 1 uses the same light source and different crayons, so the experiment makes sense. Using the same light source that makes the experiment fair because we can see which crayon melts first correctly. But group 2 use 3 light sources to experiment will not be fair because if one of the light sources is hotter than the other, that crayon will melt first without knowing which color of crayon melts easiest or hardest.”

These examples demonstrate the quality of answers on item 3 with the most mixed answers responses from elementary school students.

5. Discussion and Conclusion

To summarize these findings in respect to the research topic, the VASI questionnaire revealed that the majority of students in this sample do not have an informed perspective of scientific investigation. This study showed that the highest informed answers of elementary school students is for the aspect of *conclusions consistent with data collected*. Likewise, twelfth-grade students from a public secondary school in Thailand had especially informed understanding about some aspects of NOSI consist of *conclusions consistent with data collected* and *procedures are guided by the question asked*. (Lederman et. al., 2021). In contrast, this study examined the score of nature of scientific inquiry of the elementary school students and found that the highest percentage of Naive views is shown in *multiple method* aspect in both groups, consist of elementary school students (22.73%). The only aspect that has the lowest rate was aspects 2, the multiple methods of elementary school students. These results can be described by the lack of emphasis related to doing inquiry in the classroom. Moreover, this study revealed that the new inquiry learning for elementary school students could not enhance their understanding of the method of inquiry. Obviously, there are other ways that scientists perform investigations such as observing phenomena. Consequently, elementary school students should develop an understanding of the variety of research methodologies in the classroom.

The dimension to consider when evaluating these findings is how scientific inquiry is depicted in the science curriculum in Thailand. Regarding curriculum reform, the ministry of education of Thailand launched a new curriculum, the 2001 Basic Education Curriculum B.E. 2544 (Ministry of Education 2001). Under this curriculum for science education, the Institute for the Promotion of

Teaching Science and Technology (IPST) — an agency under the direction of the Ministry of Education–plays a major role in reforming science education and, in 2002, established standards for science education in Thailand. This curriculum would promote students' learning to acquire scientific knowledge by using essential inquiry skills for investigations, identifying patterns from data, and solving scientific and technological problems. Moreover, the science curriculum requires all Thai science teachers to embed NOS in their science teaching. However, it does not inform science teachers on how to teach NOS. Furthermore, Ketsing and Roadrangka (2010) indicated that the major difficulty is teachers' misconception of inquiry. Science teachers only have a partial understanding of the concept of inquiry and are unaware that it is a strategy for exploring natural occurrences and that scientists utilize it to gain information based on evidence. The following section describes the future work which supports students' understanding of scientific inquiry.

6. Future Work

According to the preliminary results as abovementioned, the researchers plan to design a learning module to foster elementary school students' understanding of NOSI and their learning competencies in science subject matter, and also promote the quality of science education addressing the revised national basic education curriculum. This competency-based science learning module was designed to enhance students' understanding of scientific inquiry by using inquiry-based learning approaches that have the potential for various methods to investigate scientific phenomena. Moreover, the researchers plan to integrate various technologies into the learning activities for emphasize students experience with using digital technologies as the investigation tools in multiple methods of investigation to address the previous result of the study. In addition, numerous researchers have indicated that integrating digital technology into inquiry-based learning activities could engage learners' interaction and also promote their conceptions about science while learning science (Premthaisong & Srisawasdi, 2020; Premthaisong, Pondee & Srisawasdi, 2017; Pondee, Premthaisong & Srisawasdi, 2017; Phouthavong & Srisawasdi, 2016). To foster elementary school students' understanding of NOSI, a series of science learning module named "Water is Life" which includes three layers of competency-based learning activity consisting of (i) NOSI with typical scientific inquiry endeavor related to the Alaskan Grizzly bear and salmon migration, (ii) NOSI with specific context of scientific inquiry processes on how to determine water quality and intervene water cycle for living applications, (iii) NOSI with fake news related the science of water in daily life, respectively.

To provide meaningful and interactive learning experiences to elementary school students and improve their understanding of NOSI, a rich of digital learning environment has been developed to achieve that. In the digital learning environment, students were systematically assigned to interact with several kinds of digital learning materials for the learning of the eight aspects of NOSI through an integration of Moodle learning management system and H5P user-generated content technology. For their interaction, interactive H5P video presentation embedded NOSI components in all eight aspects in the Alaskan Grizzly bear and salmon migration scenario. This video shows natural phenomena and how scientist work to find the answer to why salmon swim upstream and can back to their home. In the video, students will interact with different kinds of interactive elements, and they can also monitor learning progression through the results of video interaction. In the second activity, students collaboratively interact with a digital board game to learn the science concept of water cycle. After, students were assigned to interact with hands-on laboratory stations that encourage students to understand multiple methods of scientific inquiry focusing on water quality concept. For the next activity, students were allowed to encounter fake news related natural water situation to foster their NOSI implementation toward current social life. Table 2 shows the three layers of competency-based learning activity to foster elementary school students' NOSI.

Table 2. *The Three Layers of Competency-based Learning Activity for NOSI Development*

Learning Competencies	Learning strategy	Learning tools	
NOSI with typical scientific inquiry endeavor			
To be able to understand the nature of scientific inquiry	Inquiry-based learning with interactive video	Interactive video	
NOSI with specific context of scientific inquiry processes			
To be able to create a model to explain water cycle phenomena	Inquiry-based with digital board game	Digital board learning Game	
To able to investigate as scientific practice about applying water in daily life	Hands-on inquiry-based practical work	Microcomputer -based learning	
NOSI with fake news			
To be able to use the nature of scientific inquiry to investigate problem	Inquiry-based learning with interactive video	Video interactive & Microcomputer -based learning	

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