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The Effects of Inquiry-based Learning Activities to Understand the Nature of Science of Science Student Teachers

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Understanding the nature of science (NOS) is one of the main components for science students to be science literate people. It is also important for science teacher students to develop their NOS understanding to be relevant to an informed view. Therefore, this study investigated the effects of Inquiry process learning activities through a reflective explicit approach and the history of scientists on science student teachers, understanding NOS through mixed-method research. The samples were 35 science student teachers in the general science program at Yala Rajabhat University, Thailand. The research instruments included (1) inquiry-based learning through the reflective explicit approach and the history of scientists lesson plans, (2) the NOS understanding questionnaire, and (3) a semi-structured interview about the NOS understanding. The data were statistically analyzed in terms of percentage, mean, standard deviation, t-test dependent samples, and content analysis. The results revealed that the mean scores of the NOS understanding of the science teacher students taking part in the inquiry-based learning activities through the reflective explicit approach and the history of scientists after learning were higher than those before learning, with the statistical significance at .05. After the learning, most of the students had informed view (IV) of all NOS aspect. The research suggests that Inquiry-based learning activities through the reflective explicit approach and the history of scientists can promote an understanding of the nature of science. It should be used in science learning management to develop students' understanding of the nature of science.

Keywords: nature of science, the inquiry process, reflective explicit approach, history of scientists, learning activities

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INTRODUCTION

Literacy in scientific fields should be attained as the primary objective of science education (Khishfe, 2022). People who become scientifically literate are not only those who understand scientific concepts, but also those who can apply scientific knowledge to make decisions about themselves and both scientifically and non-scientifically social contexts (Leblebicoglu et al., 2019). This includes an understanding of scientific inquiry and the nature of science (Lederman & Lederman, 2019).

As a result, the nature of science (NOS) is regarded to be one of the components that is necessary to transform learners into persons who are scientifically literate. It is also a philosophy concerning the theories of scientific knowledge, scientific features, and techniques to gain scientific knowledge through investigating knowledge and society, belief, and value in scientific knowledge (Lederman et al., 2002). The American Association for the Advancement of Science (AAAS, 1993) suggests that the essence of science may be broken down into three distinct components. These components include a scientific world view, scientific inquiry, and scientific enterprise. There is a connection between the many contexts in which we find ourselves and the scientific method. It is possible for scientific education to be a failure according to the tenets of the philosophy of science learning if the nature of science is ignored in the management and application of scientific information (Prachagool & Nuangchalerm, 2019).

Additionally, scientific learning may be effectively facilitated when learners have an accurate and suitable understanding of the nature of science. Furthermore, learners can have a greater interest in science and a more positive attitude toward science when they have this understanding (Bugingo et al., 2022). Learners are therefore able to contribute to the improvement of science literacy, have the ability to make judgments, and apply the knowledge or techniques of science to address their personal difficulties as well as challenges faced by society (Clough, 2018).

Teachers are considered one of the factors playing an important role in each learner's development of understanding the nature of science (Buaraphan, 2018). However, according to some previous studies in the last few years, it was found that most teachers incorrectly understood the nature of science in several aspects (Saif, 2016; Narbona et al., 2023) In addition, when understanding of the nature of science of pre-service teachers, who were main manpower to develop learning management of science nature for learners, was considered, it was found that their understanding of the nature of science was the adequate view (Dorsah, 2020; Sade Memisoglu & Ercelik, 2022).

Having learning activities that encourage students to engage in scientific inquiry, which is the primary instrument used by scientists to acquire scientific knowledge and gain an understanding of scientific processes and methods, (Hastuti et al., 2020; Rafiq et al., 2023) and one of the ways that science teacher students can be developed to have an accurate understanding of the nature of science as a consequence of this, students are able to apply the information they gain in the classroom to their own scientific work and get an understanding of the activities and responsibilities played by scientists in society (Tal et al., 2019). However, solely inquiry-based learning, which does not include indication and reflection on ideas concerning the essence of science, is unable to increase science students' understanding of the nature of science (Abd-EL-Khalick & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002).

Various research works (Gathong & Chamrat, 2019; Matin, 2023) found that Learning management to promote learners to understand the nature of science was found to be indicative and explicit reflective learning management, which can be used to integrate the nature of science into science lessons or specific learning activities unrelated to any science lesson for students to learn clearly (Khishfe; & Abd-El-Khalick, 2002; Schwartz; et al., 2004). This type of learning management can also encourage an understanding of the nature of science and increase the learner's capacity to retain information on the nature of science (Khishfe, 2015; Mulvey & Bell, 2017). However, inquiry-based learning together with a reflective explicit approach could not be promoted to understand the nature of science in terms of science enterprise (AAAS, 1993) because science is a social activity, and science, technology, and society can affect each other; consequently, learning management by using science history (Ampatzidis & Ergazaki, 2023) can assist learners in seeing the development and changes of science until they are able to have more scientific knowledge (Clough, 2018).

In Thailand, there were fewer research works about science student teachers despite the fact that international research works were promoted for learning management to understand the nature of science by scientific inquiry through the reflective explicit approach and science history (Nur & Fitnat, 2015; Pekbay & Yilmaz, 2015; Nyarko & Rudge, 2022). This was the case despite the fact that international research works were promoted for learning management to understand the nature of science by scientific inquiry through the reflective explicit approach. The growth of these instructors' ability to accurately comprehend the nature of science should be encouraged by providing a variety of learning activities that focus on diverse aspects of the nature of science. Due to the aforementioned issues and factors, it is clear that science student teachers need to be provided with opportunities to engage in learning activities that are based on inquiry.

These activities should be developed using the reflective explicit approach and should include a history of scientists. The subject that was being investigated for this piece of the study was, "How do instructors comprehend the nature of science after having been exposed to science activities via the reflective explicit approach and the history of scientists?"

METHOD

This research was conducted by a convergent design (Creswell, 2018) by analyzing both qualitative and quantitative data together or collecting discrete data and analyzing both sets of data to compare and interpret the understanding of NOS of science student teachers.

Participant

35 third-year students of the Bachelor of Education Program in General Science, the Faculty of Science, Technology, and Agriculture, Yala Rajabhat University, Thailand.

Variables

Independent variables are inquiry-based learning activities through the reflective explicit approach and the history of scientists containing 5Es-Engagement, Exploration, Explanation, Elaboration, and Evaluation (IPST, 2002) as shown in Table 1.

Table 1
Steps and details of 5Es of inquiry-based learning

Steps	Details of 5Es of inquiry-based learning
Engagement	The engagement was a starting step of learning activities that encouraged learning through the connection between learners' experiences and ongoing lessons.
Exploration	the learners took their time to explore and search for their own ideas. This step was aimed at creating experiences for the learners to learn scientific ideas and science process skills by exploring materials and situations, and applying such skills as observation, hypothesis testing, problem-solving, and variable identification.
Explanation	the learners should explain what they learned by themselves, and then the teachers could give a scientific presentation. Therefore, the activities in this step should be focused on explanation by learners and links between interest creation and the exploration step.
Elaboration	a step to help the learners to have wider knowledge through cooperative learning and group discussion since the learners should express their opinions and exchange their ideas with others as well as obtain data from their classmates at the same time.
Evaluation	a step to support the learners to evaluate their understanding and ability, and the teachers could also assess the development of the learners according to the expected learning outcomes.

In terms of the history of scientists, each learning activity was displayed in Table 2:

Table 2
The History of scientists in each learning activity

Learning Activity	The History of scientists
Learning Activity 1	Atomic Models by Dalton, Thomson, Rutherford, and electron cloud
Learning Activity 2	Darwin's Theory of Evolution
Learning Activity 3	Refraction by Claudius Ptolemy, Ibn al-Haitham, and Willebrord Snell
Learning Activity 4	Sulfuric Acid discovery by Al-Razi and Ibn al-Haitham and Acid-Base Theory by Arrhenius, Bronsted-Lowry
Learning Activity 5	Gregor Mendel's Law

There were five 4-hour learning plans, in a total of 20 hours: (1) secrets under the box and evolution of atomic models, (2) dinosaur fossil puzzles, (3) why we see objects slantingly in a water glass, (4) acid or base, and (5) why our appearances are not similar. All these plans were inspected by three scientific experts. The evaluation results showed that the index of consistency (IOC) of the learning plans by inquiry process along with the reflective explicit approach and the history of scientists was between 0.67-1.00.

The dependent variable is the Understanding of the nature of science.

Research instruments

There were three research instruments: 1) inquiry-based learning through the reflective explicit approach and the history of scientists lesson plans 2) the understanding of the nature of science questionnaire, and 3) a semi-structured interview about the understanding of the nature of science.

1) inquiry-based learning through the reflective explicit approach and the history of scientists lesson plans were five 4-hour learning plans, in a total of 20 hours: (1) secrets under the box and evolution of atomic models, (2) dinosaur fossil puzzles, (3) why we see objects slantingly in a water glass, (4) acid or base, and (5) why our appearances are not similar. All these plans were inspected by three scientific experts. The evaluation results showed that the index of consistency (IOC) of the learning plans by inquiry process along with the reflective explicit approach and the history of scientists was between 0.67-1.00. A sample of a learning plan is as follows

Table 3
Learning Activity 2: Dinosaur Fossil Puzzle - Steps and Details

Steps	Detail of Learning Activity 2: Dinosaur Fossil Puzzle
Engagement	1.Divide students into groups of 5 or 6, ensuring mixed abilities within each group. Introduce augmented reality (AR) dinosaurs to spark interest and poses the following questions to the students: “What did you notice when observing the AR dinosaurs?” (Potential answer: Each type of dinosaur) “How do scientists determine the shape of each dinosaur species?” (Potential answer: Through the study of dinosaur fossils and bones) 2.Ask the students to watch a video about fossils (through this link: https://www.youtube.com/watch?v=0JU9MffzOB0). Then, facilitate a discussion by raising the following questions: “What did you observe in the video?” (Potential answer: Dinosaur bones and fossils) “How do scientists identify or determine the age of fossils?” (Potential answer: Through observations, inferences, and evidence) “If you were a scientist, how would you conduct inquiries to gather information about dinosaurs?” (Potential answer: Through fossil exploration and observation)
Exploration	3. Have the students watch a video showcasing scientists studying dinosaurs for seven minutes (video link: https://www.youtube.com/watch?v=0JU9MffzOB0). Subsequently, initiate a discussion by asking the following questions: “What observations did you make from watching the video?” (Potential answer: The work of scientists studying dinosaur fossils) “How do scientists conduct their studies?” (Potential answer: Through observations, inferences, and evidence) 4. Display three PowerPoint slides illustrating animal fossil fragments, including 1) a bird, 2) a turtle, and 3) a great white shark. Allocate 20 minutes for students to observe and record the data provided on their papers. Additionally, instruct them to utilize Jam board to depict potential living organisms corresponding to the displayed fossils visually.
Explanation	5. Ask each group to choose a representative to present the possible living organisms they drew from the fossils on the Jamboard. Afterward, pose the following questions to the students: “What methods did you utilize to depict the missing fossils?” (Potential answer: Observation, inference, and evidence from other fossil fragments)

Steps	Detail of Learning Activity 2: Dinosaur Fossil Puzzle
	6. Reveal the answers to the fossil illustrations of the three types of animals. Then, proceed with the following questions for the students: "Did your group's conclusions align with those of the scientists?" (Potential answer: Yes or no) "What did you rely on to determine the type of living organism?" (Potential answer: Observation, inference, and evidence) "What data or clues have led scientists to reach such conclusions?" (Potential answer: Fossil fragments, imagination, and experience) 7. Explain and reflect on the nature of science by stating: "Scientists confidently arrived at their conclusions by comparing them with real fossils to ensure consistency. Fossils serve as valuable records supporting these creatures' existence on Earth. Scientists estimate the age of fossils based on the age of the sedimentary rock layers in which they are preserved. These sedimentary rock layers not only provide clues to the evolution of life over time but also serve as crucial evidence contributing to new knowledge and discoveries. This highlights the significance of evidence in shaping scientific knowledge and how scientific understanding can evolve with verifiable empirical data and evidence."
Elaboration	8. Let the students watch a six-minute video about the use of dinosaur GPS (video link: http://science.unctv.org/content/dinosaur-gps). Then, engage the students in a discussion by asking the following questions: "How do scientists study the evolution of dinosaurs?" (Potential answer: Evidence and dinosaur GPS) "In what ways does the use of dinosaur GPS demonstrate the interplay between science and technology?" (Potential answer: The relationship between science and technology, with technology aiding scientists in gathering more evidence about dinosaurs) 9. Allow the students to watch a video clip about the evolution of dinosaurs (video link: https://www.youtube.com/watch?v=sNagbXkwTi4). Then, prompt the students with the following questions: "How do scientists acquire knowledge about the physical characteristics of dinosaurs?" (Potential answer: Evidence, imagination, and creativity) "Why has our understanding of dinosaurs changed over time?" (Potential answer: The replacement of old with new knowledge based on verifiable evidence) "What methodologies do scientists employ to gather data about dinosaurs?" (Potential answer: Experimentation, observation, inference, imagination, and creativity) Reflect on the interrelatedness of science, technology, and society by explaining that these three components are deeply intertwined. Technological advancements not only aid scientists in conducting research but also pave the way for the creation of more extensive scientific knowledge. This new knowledge, in turn, has the power to enhance people's quality of life. The acquisition of scientific knowledge is not limited to a single method. It can be obtained through a range of approaches, including observation, exploration, rational reflection, creativity, and imagination. Some areas of scientific knowledge require experimentation, while others hinge more on observation, exploration, creativity, and imagination. Additionally, experiments may be used in conjunction with other scientific inquiry processes. 10. Ask the student to complete an activity sheet on Charles Darwin's perseverance. Then, join the students in a whole-class discussion by asking the following questions: "How does society affect the work of scientists based on the findings from Charles Darwin's work?" (Potential answer: Society and culture playing a pivotal role in shaping the work of scientists and social opposition potentially putting a pause on progress) "How do society and culture influence the work of scientists, considering the statement: 'In some religious and theistic societies, even in a society known as the most advanced in modern science like American society, schools in many states are forbidden from teaching

Steps	Detail of Learning Activity 2: Dinosaur Fossil Puzzle
	Darwinian theory'?" (Potential answer: Society and culture playing a pivotal role in shaping the work of scientists, and social opposition potentially putting a pause on progress) "What was the basis on which Charles Darwin developed his scientific theory, as evidenced by his work?" (Potential answer: Verifiable empirical evidence, such as observations, inferences, and exploration) Reflect on the nature of science by highlighting that the presence of verifiable empirical evidence leads to the replacement of old with new knowledge. Consequently, scientific understanding is subject to change. Furthermore, scientists employ various approaches beyond experimental methods, including observation, inference, exploration, imagination, and creativity. The steps involved in scientific inquiry can be flexible and uncertain, often interchanging in sequence.
Evaluation	12. Share a link to Jam board with the students and instruct them to answer the following questions and provide explanations on the board based on the following topics: 1. The nature of science learned from the activities. 2. Is there a universal scientific method with fixed steps? Why? 3. How does the work of scientists rely on imagination and creativity? In what ways? 4. What do scientists use to confirm the acquisition of scientific knowledge? Why? 5. What scientific process skills do scientists employ to derive data on dinosaur fossils and other ancient-life fossils? 6. How do society and culture influence the work of scientists? 13. Instruct the students to share ideas and answer the given questions. 14. Organize a gallery walk activity to facilitate the exchange of learning. Implement the following methods: - Ask each group representative to present their boards through Google Meet. - Allow each group of students to use a pen to make additional contributions to the boards. - Prompt each group to study the poster of the next group for three minutes, studying their findings from the activity. Instruct the students to summarize their findings and express their agreement by placing a check mark (✓) beside the points they find compelling. Conversely, if they hold differing opinions, ask the students to write down their inputs. Also, tell the students they may use a question mark (?) on undecided issues. - Rinse and repeat the process until the students complete the activity for all posters. - Engage the students in a collective discussion, bringing them together to reflect upon their learnings from the activity and deep dive into the insights it offers regarding the nature of science.

2) The understanding of the nature of science questionnaire contained five rating scales of 'extremely agree', 'agree', 'be unsure', 'disagree', and 'extremely disagree' for texts in which the teacher students had to express their opinions about situations to understand the nature of science covering three components of scientific world view, scientific inquiry, and scientific enterprise. In fact, this questionnaire was developed by Safkolam et.al. (2021) and Prachagool & Nuangchalerm (2019). In addition, there were seven aspects of the nature of science: NOS 1 scientific knowledge is tentative, NOS 2 checkable scientific knowledge with empirical evidence, NOS 3 various scientific methods without fixed steps, NOS 4 society and cultures influencing scientists' working, NOS 5 science based on observation and inferring with different ideas, NOS 6 science based on imagination and creativity, and NOS 7 science technology and society affecting each other. The questionnaire was also checked for the index of consistency (IOC) with the aspect of NOS, which was between 0.67-1.00, and piloted by 30 non-target students to find out reliability by Cronbach's alpha coefficient, resulting in 0.83.

3)The semi-structured interview about the understanding of the nature of science included two open-ended questions about 'why' for each aspect of NOS. The interview was checked for the index of consistency (IOC) with the aspects of NOS, which was between 0.67-1.00, by three scientific experts. It was also piloted by non-target students, and it was found that the students understood questions and could answer the questions as purposed.

Data collection was conducted for both quantitative and qualitative data. Before the learning activities, the teacher's students responded to the questionnaire about the understanding of NOS. then, their understanding was analyzed and divided into three groups according to the nature of science by Niyomwong (2015) as shown in Table 5 (quantitative criteria). After that, seven representatives of the teacher students in each group were selected to be interviewed by the semi-structured interview for 10-15 minutes each. During the interview, the records were asked for permission. Next, five learning plans were applied to the teacher students, and these seven students had to answer the same questionnaire again. Finally, all the data were analyzed.

Data analysis was separated into two parts: quantitative analysis and qualitative analysis

Analysis of quantitative data

1. All the answers to the questions in the questionnaire were analyzed and interpreted into scores by the criteria of Rubba & Andersen (1978) as displayed in Table 4.

Table 4
Comment Score of positive and negative message

Comment	Positive message (score)	Negative message (score)
Extremely agree	5	1
Agree	4	2
Be unsure	3	3
Disagree	2	4
Extremely disagree	1	5

2. The scores were calculated for the overall mean and each aspect's mean. Then the calculation results were analyzed by t-test for dependent samples to find out the mean difference of the samples before and after the inquiry-based learning activities through the reflective explicit approach and the history of scientists.

3. The mean scores were interpreted to group the understanding of NOS according to Niyomwong (2015) as shown in Table 5.

Table 5
Groups of the understanding of NOS, Explain of the group and mean scores

Groups of the understanding of NOS	Explain of group	Mean scores
Informed view (IV)	was used to explain the group of students consistent to the nature of science, excepted nowadays.	3.41-5.00
Transitional view (TV)	was an explanation of the students consistent to the nature of science, partly excepted nowadays and incomplete as well as the students consistent to the nature of science partly excepted nowadays and inconsistent to the nature of science, partly excepted nowadays.	1.71-3.40
Naïve view (NV)	was described for the students inconsistent to the nature of science, excepted nowadays or the students answering questions with unrelated issues, or the students who did not answer any questions or express any opinions.	lower1.71

Analysis of qualitative data

1. All the interview data before and after the inquiry-based learning activities through the reflective explicit approach and the history of scientists were gathered.

2. The data were analyzed by content analysis (Schreier, 2012) in order to divide into three groups of understanding of NOS as described in Table 5.

3. The accuracy and reliability of the results were inspected, and the analysis and interpretation of the results were submitted to the NOS experts to compare changes of NOS understanding of the students before and after learning in terms of each NOS aspect. The interview data were not mentioned to each student's name, but each student was numbered instead such as student 7, student 14, etc.

The analysis results of the questionnaire data (quantitative data) and the interview data (qualitative data) were compared to conclude the NOS understanding of the students before and after the learning activities.

FINDINGS

This research was conducted to evaluate the understanding of the nature of science before and after the activities by using the questionnaire and the semi-structured interview asking about the NOS understanding. In terms of the questionnaire, the results showed that the mean scores of each aspect of the NOS understanding after the lessons were higher than those before the lessons with the statistical significance at .05 as shown in Table 6.

Table 6
The comparison of the pre-test and post-test mean scores of the understanding of NOS

Aspect of NOS	N	Pre-test $\bar{x}_1$	S.D.	Post-test $\bar{x}_2$	S.D.	t	p
NOS 1	35	3.35	0.42	4.34	0.50	- 8.314*	.000
NOS 2	35	3.40	0.38	4.06	0.59	- 12.497*	.000
NOS 3	35	2.89	0.41	4.36	0.49	- 12.417*	.000
NOS 4	35	3.26	0.54	4.19	0.43	- 2.930*	.000
NOS 5	35	3.32	0.39	4.32	0.44	- 11.067*	.000
NOS 6	35	2.97	0.67	4.27	0.58	- 8.445*	.000
NOS 7	35	3.33	0.40	4.42	0.44	- 5.334*	.000
Overall	35	3.21	0.46	4.28	0.50	- 6.393*	.000

*$p < .05$

Furthermore, the results of the interview with seven students before the class indicated that most of the students understood each NOS aspect at a transitional view (TV) level. Five of all aspects were 100% of transitional view. Other two aspects scientific knowledge is tentative (NOS1) and science based on imagination and creativity (NOS6) of some students were group into a naïve view (NV), with 14.27% and 28.57%, respectively. Interestingly, there were no students who understood NOS had an informed view (IV).

After the inquiry-based learning activities through the reflective explicit approach and the history of scientists, it was found that all the students understood six NOS aspects had an informed view (IV) (100%). Except, 85.73% of the students understood the aspect of various scientific methods without fixed steps (NOS 3), had an Informed view, and 14.27% of them understood had transitional view (Table 7).

Table 7
Percentage of the students' view of NOS before and after learning according to the interviews

Aspect of NOS	Frequency (Percentage) of students' views of NOS before and after learning					
	IV		TV		NV	
	Before	After	Before	After	Before	After
NOS 1	0 (0.00)	7 (100)	6 (85.73)	0 (0.00)	1(14.27)	0 (0.00)
NOS 2	0 (0.00)	7 (100)	7 (100)	0 (0.00)	0 (0.00)	0 (0.00)
NOS 3	0 (0.00)	6 (85.73)	7 (100)	1 (14.27)	0 (0.00)	0 (0.00)
NOS 4	0 (0.00)	7 (100)	7 (100)	0 (0.00)	0 (0.00)	0 (0.00)
NOS 5	0 (0.00)	7 (100)	7 (100)	0 (0.00)	0 (0.00)	0 (0.00)
NOS 6	0 (0.00)	7 (100)	5(71.43)	0 (0.00)	2(28.57)	0 (0.00)
NOS 7	0 (0.00)	7 (100)	7 (100)	0 (0.00)	0 (0.00)	0 (0.00)

In Table 8, the interview results of each NOS aspect were displayed.

Table 8
The interview results of each NOS aspect before and after learning

NOS Aspect	Before learning	After learning
NOS 1	"In the future, there will be an instrument to discover new planets." (S1) (TV)	"When a scientist discovers new knowledge and enough empirical evidence supports it, this evidence can be used to replace the old knowledge. For example, there are eight planets, so the new knowledge with clear evidence can replace the old knowledge." (S1) (IV)
	"Science is uncertain, and any circumstance can be changed. When I was in primary school, I knew that there were nine planets in the universe, but now there are only eight because one of them was outside the universe, which could be found or could not be found in the future. The number of planets could be lower or change again. Scientific knowledge can be discovered anytime in the future, and certainly, new planets which do not appear now can be discovered soon." (S9) (NV)	"When technology is more advanced, discoveries by scientists are more possible. For example, for the telescope, in the past, people hardly saw stars in the sky with their naked eyes. After the telescope was invented, people could see more stars in the sky. It could reflect that scientific knowledge can be changed with new and obvious evidence that can be described and then accepted, resulting in removing this old knowledge. Another example is Dalton's atomic model stating that an atom was in an opaque sphere shape. This information was just described without any experiments. After that Thomson, another scientist experimented it and explained with empirical evidence until his information was more reliable than Dalton's; therefore, Dalton's data were erased and replaced with Thomson's. It could be clear that scientific knowledge can be changed." (S9) (IV)
NOS 2	"To be accepted by scientists, information needs evidence to confirm that our theory or idea can be possible." (S2) (TV)	"Discoveries of scientific knowledge do not always need evidence because an experiment can be evidence, but imagination and creativity should come with evidence." (S2) (IV)
	"Discoveries of scientific knowledge always need evidence because clear evidence can be used to describe to accept something new." (S6) (TV)	"Scientific methods are various. An experiment can be used as evidence, but some scientific knowledge discoveries do not depend on experiments, but depend on imagination and creativity, resulting in no evidence. Therefore, scientific knowledge do not always come with evidence such as Dalton's atomic model which was confirmed by an experiment but accepted." (S6) (IV)
NOS 3	"Scientific steps are important and in order. When some steps are skipped, mistakes can appear." (S4) (TV)	"Scientific knowledge can be found out by various methods without fixed steps. That is, a scientist can swap steps such as an observation step before an experiment step or an experiment step before an observation step." (S4) (IV)
	"Scientific process contains its steps such as a primary step, a hypothesis step. When the steps are swapped, there can be mistakes." (S12) (TV)	"There are no fixed steps to gain scientific knowledge. For instance, in Darwin's theory, he observed to find out some scientific knowledge. Dalton started a step of imagination to gain his scientific knowledge. It can be seen that there are no fixed steps; some steps can be switched to each other; an observation step or an experiment step can be the first step." (S12) (IV)
NOS 4	"If a scientist is opposed to an experiment, he will pause his experiment for a while, but his knowledge is still with him always." (S6) (TV)	"A scientist will stop but just for a while, and he will seek for new methods to make his work successful." (S6) (IV)

NOS Aspect	Before learning	After learning
	"If a scientist was experimenting but was opposed, he would pause once to search for more information. However, if he thought his experiment was good enough, he would continue to do it." (S15) (TV)	"If some scientific knowledge is in conflict with some people's beliefs, his experiment to prove the knowledge will be suspended or opposed. For example, Mendel's experiment was suspended since people thought his idea was natural, and he will make this nature have errors. It was clear that society and cultures influenced on scientists a lot." (S15) (IV)
NOS 5	"Observation and taking action are not in the same step. Only observation and observation before inferring are also not the same step." (S3) (TV)	"Observation and inferring are different. Observation contains five senses of touching, smelling, using, hearing, seeing, and tasting. Inferring happens after observation plus own experience and own feelings. For examples of observation, a tree is green; a sky is blue, clouds are in shape that we see. However, an example of inferring is that we see one girl with her stressful face, so we infer that she could have been stressed or thinking too much." (S3) (IV)
	"Observation and inferring are not the same process. Observation is observation, but inferring needs reasons." (S14) (TV)	"Observation needs senses without own feelings to describe the information we are observing, but inferring is to express opinions from observation through own experiences. For example, if we observe a fossil piece, we will see something shape, and we will infer through our experiment that it could be a beak of a bird. Our friends could also infer something different such as a chicken or a duck depending on their own experiences." (S14) (IV)
NOS 6	"Imagination cannot be with science because science contains experiments and observation, and we cannot imagine anything without intention." (S10) (NV)	"Obtaining scientific knowledge requires creativity and imagination in every step. For example, regarding the discovery of Dalton's atomic model, he only used his imagination and creativity but did not conduct any experiments, and so did Rutherford. He applied his imagination and creativity in every step including planning, inquiry process design, interpretation, and summary with different conclusions." (S10) (IV)
	"Our data will be complete with imagination and creativity in order to know which direction the data should be." (S18) (TV)	"To obtain scientific knowledge, a scientist should employ creativity and imagination in every step. For instance, the explanation of Dalton's atomic model showed that his knowledge came from his imagination. Therefore, imagination and creativity can be used to acquire scientific knowledge." (S18) (IV)
NOS 7	"Science and technology are in the same content because science is matched with technology, and technology is used to search for scientific knowledge." (S2) (TV)	"Science and technology are not in the same content because science is knowledge from theories or rules, but technology is to bring knowledge to create new things to respond to people in society such as satellites, televisions, telephones, and cars, which are by-product technology from scientific knowledge in various fields." (S2) (IV)
	"Science and technology are in the same content because learning any field of science needs the use of technology. If there is no technology, there will be some effects on science because we cannot study science." (S4) (TV)	"Scientific knowledge is used to explain any natural incidents reasonably, but the technology was developed from scientific knowledge to be innovation in order to facilitate many things. Therefore, science is related to technology, but they are not the same." (S4) (IV)

When the results of the questionnaire asking about the NOS understanding (quantitative data) and the interview about the NOS understanding (qualitative data) were considered, it was indicated that after the inquiry-based learning activities through the reflective explicit approach and the history of scientists, most of the students understood NOS had informed view for all aspect. In fact, before class, most of them understood NOS had a transitional view. The results of the questionnaire and the interview were consistent.

DISCUSSION

After participating in inquiry-based learning activities that focused on the reflective explicit approach and the history of scientists, the vast majority of the students demonstrated an informed view (IV) level of comprehension of the NOS, as indicated by the results of the questionnaire and the interview regarding this concept. According to the research conducted by Akerson et al. (2014), learning management included the following four contexts: (1) teaching and learning activities of NOS; (2) learning management with a reflective explicit approach; (3) problem-based learning management together with a reflective explicit approach of NOS; and (4) inquiry-based learning management for science primary teacher students to better understand NOS. The findings of this study were consistent with the findings of this research.

In point of fact, the inquiry-based learning that the students participated in was centered on the students engaging in conversation, searching, and learning the scientific working process. Additionally, inquiry-based learning provided opportunities for the students to receive direct experiences, discover scientific principles, practice scientific process, and use scientific methods to solve their problems amongst their peers. These kinds of chances might create an atmosphere conducive to individual learning, which would result in increased motivation and encouragement for students' academic pursuits as well as the growth of knowledge of NOS (Yenice, 2022) and learning through the history of scientists and a reflective explicit approach of NOS could influence students to understand more NOS (Dai et al., 2021) because reflection during the learning sessions can make students link NOS to incidents in their daily life and the relationship between science, technology, and society (El Islami & Nuangchalerm, 2020; Shi, 2020).

Additionally, the fact that the students were required to discuss scientific concepts and NOS in their own groups as part of the learning exercises meant that the findings may be impacted by this kind of instruction. In this environment, the students were given a good opportunity to discuss, argue, question, and exchange their opinions with one another in order to recheck their understanding and solve some mistakes (Lederman, 1992). This included changes and development of the student’s understanding of NOS, which was also a part of the study (Wolfensberger & Canella, 2015).

The materials that give students questions about the nature of science give them the chance to discuss the nature of science and reflect on it while also giving them the opportunity to be able to respond to questions, which is another crucial component. The scientific method notion will be better understood by pupils if they can relate examples from the lives of many scientists from the past. Students will be able to comprehend the nature of science if discussion questions are used to create chances for reflection and discussion on the nature of science (Oh & Lederman, 2018). Another possibility could be that the teacher offers talks, questions, and explanations that are tailored to particular NOS elements. It is possible for teachers to plan activities that foster students' comprehension of the nature of science when they have an in-depth awareness of both the nature of science and the management of learning it (Cofre et al., 2019).

The ways in which pre-service teachers interpreted NOS revealed the level of NOS comprehension they possessed. They stated that NOS is the mixture of worldviews, the process of knowledge building whose output and process impact societal values, and the conjunction of these two things. In addition, they were aware that the term "nature of science" (NOS) refers to the epistemology and sociology of science, the concept of science as a mode of knowing, as well as the attitudes and beliefs that are inherently associated with the production of scientific knowledge (Juhji & Nuangchalerm, 2020). Science was able to convey to the participants an understanding that it could describe actual information, natural occurrences, and other environments. In other words, it indicated that they have had favorable views towards science and, more precisely, their understanding of how science is taught and how it is learned.

CONCLUSION

The science teacher students participated in the inquiry-based learning activities through the reflective explicit approach and the history of scientists and their mean scores of the NOS understanding after the lessons were higher than those before the lessons, with the statistical significance at .05. Most of the students understood the NOS had informed view (IV) of every aspect.

The results indicated that the inquiry-based learning activities through the reflective explicit approach and the history of scientists could promote the NOS understanding of the science teacher students. Therefore, the factors affecting changes of the NOS understanding of the science teacher students taking part in the inquiry-based learning activities through the reflective explicit approach and the history of scientists should also be investigated. Moreover, questions used for the NOS understanding were important. If the prepared questions cannot make the students understand, the teacher should try to explain or change to other questions which were easier for the students to understand. Besides, the teachers of science subjects should bring inquiry-based learning activities through the reflective explicit approach and the history of scientists to teach other science teacher students or other students in other fields related to science and science education at a graduate level in order to promote these students to understand NOS correctly.

Additionally, this learning activity can be modified to plan academic service projects for science teachers at the primary and secondary levels and can be turned into training programs to improve the teachers' comprehension of the nature of science. A method to gauge one's comprehension of the nature of science was also created as part of this research. In order to establish a foundation for future study, the tool should be employed in comparative studies of science student instructors' comprehension of the nature of science each year.

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