JPII 13 (3) (2024) 423-436

Jurnal Pendidikan IPA Indonesia

https://journal.unnes.ac.id/journals/jpii

LEARNING RETENTION OF PRESERVICE SCIENCE TEACHERS ABOUT THE NATURE OF SCIENCE: AN EXPLICIT REFLECTIVE INQUIRY-BASED LEARNING AND HISTORY OF SCIENTIST

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DOI: 10.15294/jpii.v13i3.4411

Accepted: May 06th, 2024. Approved: August 29th, 2024. Published: August 29th 2024

ABSTRACT

Understanding the nature of science is one component of knowing science and is critical for preservice science teachers. Therefore, the researcher was interested in studying the persistence of understanding the nature of science among preservice science teachers after the course with a series of inquiry-based learning activities combined with reflective indication and history of scientists for one month using a combination of research methodology. The target group for the research was 35 preservice science teachers at Rajabhat University in Southern Thailand. The research tools included 1) a learning management plan, 2) a questionnaire on understanding the nature of science, and 3) a semi-structured interview form on understanding the nature of science. Quantitative data analysis included percentage, mean, standard deviation, and t-test for the dependent sample, while qualitative data included content-oriented analysis. The results show that preservice science teachers who studied with the learning activity set had a statistically significant average score of understanding the nature of science after a one-month learning gap, not statistically significantly different from after the course, at a level of .05. All scientific community resolutions feature the nature of science. The results indicate that incorporating the inquiry process into teaching, along with an explicit reflective approach and the historical context of scientists, can significantly enhance the student's understanding and learning retention of the nature of science.

Keywords: explicit and reflective approach, history of scientist, inquiry-based learning, learning retention, nature of science

INTRODUCTION

Understanding the nature of science affects the development of learners' scientific competencies and is an essential goal of science learning management (Irez et al., 2018; Irmak, 2020; Mahler et al., 2021). Therefore, science teachers must drive learners to understand the nature of science (Kite et al., 2021). Meanwhile, it includes preservice teachers, who are crucial to understanding and applying the nature of science in their science classes (Kinskey, 2023; Mccomas, 2020). However, according to the research, preservice science teachers need to understand the nature of science (Dorsah, 2020; Karışan & Cebesoy, 2018; Valente et al., 2018). Many scholars have conducted research to improve students' understanding of the nature of science (Çelik, 2020; Gathong & Chamart, 2019). It has been found that learning management that can encourage learners to understand the nature of science very well is learning management that indicates and reflects the nature of science.

There are many approaches, such as learning management using science, technology, and society (Attapan & Yuenyoung, 2019; Jimakorn & Yuenyong, 2018), learning management using science and technology, culture, and environment (Khan & Khan, 2022; Xiang & Han, 2024), cooperative learning management (Jampel et al.,

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2018; Wolfensberger & Canella, 2015), inquiry-based learning management (Ibrohim et al., 2020; Kinyota, 2020; Murphy et al., 2021; Schellinger et al., 2019; Zion et al., 2020). From the research above, inquiry-based learning management is the most popular and successful in promoting an understanding of the nature of science. As a result, learners learn on their own and learn the work of scientists, leading to an understanding of the nature of science (Kinyota, 2020; Kite et al., 2021; Saka, 2023).

However, teachers must be able to help students retain what they have learned about the nature of science for the subject matter to be successfully taught. Most scholars who study the retention of learning about the nature of science have conducted explicit and reflective learning arrangements through inquiry processes (Akerson et al., 2006; Khishfe, 2015). It has not been possible to develop the persistence of learning about the nature of science among learners. It was found that preservice science teachers who learned with a set of inquiry-based learning activities combined with the explicit reflective approach and history of scientists had a statistically significantly higher average understanding of the nature of science (Safkolam et al., 2024). An explicit reflective approach incorporates the nature of science into science lesson plans or activities, providing students an opportunity to discuss various aspects of NOS together. Learners will develop an understanding of the nature of science (Bugingo et al., 2024; Edgerly et al., 2023). Furthermore, studying the history of scientists can aid students in understanding the profession and community of scientists, establish a connection between how students' thinking and science concepts develop, and students are going to understand that knowledge in science is subject to change, scientists' work is influenced by society and culture (Chakravartty, 2023; Matthews, 2024).

Although research abroad has studied the permanence of learning about understanding the nature of science (Khishfe, 2015; Mulvey& Bell, 2017), it has not yet appeared in Thailand, particularly with preservice science teachers, which only develops an understanding of the nature of science. Yuenyong (2010) and Jituafua et al. (2015) state that we should develop students to be persistent in learning the nature of science. Moreover, the learning innovation developed by the researcher is a learning activity that promotes an understanding of the nature of science to science teachers and graduate students in science teaching in Thailand to complement such a body of knowledge. This study aims to investigate the persistence of learning about the understanding of the nature of science among science teachers at a university in Southern Thailand with a series of inquiry-based learning activities combined with an explicit reflective approach and the history of scientists.

METHOD

This research, which had a mixed-methods convergent design (Creswell, 2018), collected both qualitative and quantitative data by analyzing both sets of data simultaneously and combining the results of the analyses obtained from both sets of data to compare and interpret science teachers› understanding of the nature of science. The participants were third-year preservice science teachers in the general science program, at Rajabhat University in Southern Thailand. A total of 35 students obtained through a selective approach (Safkolam et al., 2024), were preservice science teachers who had completed science-related courses, including physics, chemistry, and biology. In addition, before beginning their fourth year of professional teaching experience, they were final-year students.

The research instruments used to study learning persistence were the same tools that studied the science teachers› understanding of the nature of science with a series of inquiry-based learning activities in their research (Safkolam et al., 2024). They consist of 1) a series of learning activities using the inquiry process and scientists› explicit reflection and history, 2) a questionnaire on understanding the nature of science, and 3) a semi-structured interview form on understanding the nature of science. Each research tool had been made and qualified as follows:

1) A series of learning activities using the inquiry process combined with the reflection and history of scientists, investigating knowledge (Inquiry-based learning approach: 5Es), which consists of 5 steps: Engagement, Exploration, Explanation, Elaboration, and Evaluation (IPST, 2002). This set of learning activities consists of a number of lesson management plans. The five lesson plans consist of 4 hours for each. The five learning management plans can be seen in Table 1.

Three experts in science education examined the learning activity series. The five lesson plans included 1) secrets under the box and the 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. It has a conformity index value between 0.67 and 1.00, more than 0.5 (Bergman, 1996). After improvements following the experts' recommendations, we conducted the trial on a non-target number of 30 students to determine the feasibility of conducting an event, the suitability of natural science attributes, duration of learning management, appropriateness of learning, and materials and learning resources.

2) Questionnaire on understanding the nature of science. This is characterized by an estimation of 5-level scales. The researchers updated the questionnaire on understanding the nature of the science proposed by Safkolam et al. (2021) and Prachakul and Nuengchalerm (2019). Two sets of questions (questionnaires on understanding the nature of science after class and after one month) in which texts that allow students to express their opinions are scenarios that can measure their understanding of the nature of science. They cover elements of the nature of science: scientific worldview, scientific inquiry, and scientific affairs. There are seven aspects that measure understanding the nature of science, including NOS 1 (Scientific knowledge can change), NOS 2 (Scientific knowledge must be evidence-based and verifiable), NOS 3 (The scientific method is varied, and there are no fixed steps), NOS 4 (Society and culture influence the work of scientists), NOS 5 (Science is based on observation and opinion, which is different), NOS 6 (Science relies on imagination and creativity), and NOS 7 (Science, Technology, and Society have a reciprocal impact) (IPST, 2018).

We checked the consistency of the questionnaire with three experts in science education. The assessment found that the index value was consistent with the natural characteristics of the science to be measured (IOC) between 0.67-1.00, which is more than 0.5 (Bergman, 1996). We improved and validated the questionnaire on the understanding of the nature of science based on expert recommendations and feedback. Then, we tested the questionnaire on preservice science teachers who were not target groups of 30 people to determine the confidence of the questionnaire in understanding the nature of science. The Cronbach's alpha model was found to be equal to 0.83 (Cronbach, 1990).

3) A semi-structured interview on understanding the nature of science contained questions on understanding the nature of science created by the researcher. Each question from the understanding of the nature of science was selected. Two further questions were asked: 1) What are the natural features of both sciences? and 2) What are the natural features of science?. This interview allowed students to express their opinions and reasoning about their understanding of the nature of science. To determine the quality of the interview form, we examined the consistency of interviews with three experts in science education. The assessment found that the index value was consistent with the natural characteristics of the science to be measured (IOC) between 0.67-1.00, which is more than 0.5 (Bergman, 1996). We also conducted semi-structured interviews with non-target students. The results showed that students understood the questions and were able to answer them according to the purpose:

Table 1. Lesson plans and history of Scientist

Lesson plans	History of Scientist	Aspect of NOS	Duration of learning (hours)
Secrets under the box and evolution of atomic models	Atomic Models by Dalton, Thomson, Rutherford, and electron cloud	NOS 1, NOS 2, NOS 3, NOS 5, NOS 6	4
Dinosaur fossil puzzles	Darwin's Theory of Evolution	NOS 2, NOS 3, NOS 4, NOS 5, NOS 6	4
Why do we see objects slantingly in a water glass	Refraction by Claudius Ptolemy, Ibn al-Haitham, and Willebrord Snell	NOS 1, NOS 2, NOS 3, NOS 5, NOS 7	4
Acid or base	Sulfuric Acid discovery by Al-Razi and Ibn al-Haitham and Acid-Base Theory by Arrhenius, Bronsted-Lowry	NOS 1, NOS 2, NOS 3, NOS 4, NOS 5	4

Lesson plans	History of Scientist	Aspect of NOS	Duration of learning (hours)
Why our appearances are not similar	Gregor Mendel's Law	NOS 1, NOS 2, NOS 4, NOS 5, NOS 7	4

In this study, we investigated the persistence of learning about understanding the nature of science. This continued the research examining the effects of process-based learning activities. Safkolam et al. (2024) recommended data collection after obtaining results of understanding the nature of science both before and after the class. After a month, we examined persistence in learning about understanding the nature of science. To collect data on the persistence of learning about understanding the nature of science, the details are as follows:

We measured preservice science teachers' understanding of the nature of science after the intervention, using the questionnaire to collect data online by submitting a Google Form administered to students for 60 minutes. We compiled a questionnaire to understand the nature of science and further analyzed the statistical data.

We analyzed the students' responses and categorized their understanding of the nature of science into three groups and conducted interviews with seven original students (Safkolam et al., 2024) using a semi-structured interview form which is used to measure the understanding of the nature of science by preservice science teachers students after class and one month after class. We also conducted the interview with 15 - 20 % of all target students. It can be used as an agent to judge meaning in a context relevant to the group (Lederman et al., 2002).

We personally contacted the interviewee student via mobile phone. All students agreed to be interviewed. We arranged two interview times, post-class and post-class, and one month online through Google Meet. We provided details of the students who participated in the interview. Students could withdraw during the interview.

In addition, we clarified that the purpose of the interview was to require students to express their views on understanding the nature of science. The students' responses did not contain the answer "correct" or "wrong". We were only interested in studying each of the natural features of science. Students' answers had no effect on any grade in the subjects studied. We also commented students until they understood the question clearly and showed truthful opinion to them. If students did not understand the question, they could ask for clarification or ask to hear the question again. We also asked for their consent to record the interview. We conducted the interview for 10 - 15 minutes each student.

After one month of research, we collected the findings from measuring the understanding of science's nature by analyzing quantitative and qualitative data. Research findings should be compared and contrasted to summarize the target students' understanding and retention of the nature of science.

This research was conducted using a combination of research methodologies. Hence, the data analysis was also conducted quantitatively. The researcher compiled the understanding of the nature of science questionnaire from the target group by analyzing the answers from the scores and interpreting the understanding of the nature of science using the criteria from Rubba and Anderson (1978), as shown in Table 2.

Table 2. Scores of positive and negative statements

Opinion	Positive messages (points)	Negative messages (scores)
Totally agree	5	1
Agree	4	2
Uncertain	3	3
Disagree	2	4
Strongly disagree	1	5

Using the scores obtained from the understanding the nature of science questionnaire, the average scores for the overall picture and natural characteristics of science were calculated. The sample forms were not independent of each other (t-test for dependent samples) to test for differences in the mean scores in understanding the nature of science. After organizing learning with a series of learning activities, the target group used the inquiry process accompanied by reflection and the history of scientists.

After investigating for one month, the interpretation of the average score was used to categorize the understanding of the nature of science following Niyomwong (2015), as shown in Table 3.

Table 3. The Interpretation of the Average (Mean) Scores

Groups of the understanding of NOS	Explanation	Mean scores
Informed view (IV)	was described for the students consistent with the nature of science, except nowadays.	3.41-5.00
Transitional view (TV)	was described for the students being consistent with the nature of science, partly accepted nowadays and incompletely, and the students being consistent with the nature of science partly accepted nowadays and inconsistent with the nature of science, partly accepted nowadays.	1.71-3.40
Naïve view (NV)	was described for the students inconsistent with 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.	Below 1.71

Qualitative data were obtained from the interview after the class. We transcribed the interview recordings and analyzed the interview data by content analysis (Schreier, 2012) by reading the interviews in their entirety, extracting the interview results to group the students' understanding of the nature of science, and then compiling the interview sentences in each group. Table 3 shows the explanation of each group, excluding irrelevant statements and naming interview result data. The results of the analysis were then used to verify the accuracy and reliability of the findings obtained by submitting the results of data analysis and interpretation of all characteristics of the nature of science to three experts (measurement time 1) by and after measuring the understanding of the nature of science within one month (measurement time 2) to students. For the interview results, the researcher did not include the student's last name, only the number, such as student 7 or student 14.

RESULTS AND DISCUSSION

Based on the research of Safkolam et al. (2024), it was found that preservice science teachers who learned with a series of inquiry-based learning activities combined with reflective and historical indications of scientists scored statistically significantly higher in terms of understanding the nature of science after learning compared to before learning, which was 0.05. Table 4 presents the comparison of students' average scores of understanding the nature of science after class and after one month class with a series of inquiry-based learning activities combined with reflections on the nature of science and the history of scientists.

In Table 4, we compare students' average scores of understanding the nature of science after class (Safkolam et al., 2024) and after one month class with a series of learning activities using the process of inquiry together with the reflection and history of scientists. The table shows that there is a difference of 0.5 for each feature of the nature of science. Overall, there is no difference in the average (mean) scores between after class and after one month class.

A semi-structured interview was conducted to seven students after class and after one month class. Based on the interview results after class, all students (100%) are classified as an un-

Table 4. Comparison of students' scores on the understanding of the nature of science after class and after one month study

Aspect of NOS	N	After class		After one month study		t	p
		$\bar{X}_2$	S.D.	$\bar{X}_3$	S.D.		
NOS 1	35	4.34	0.50	4.29	0.37	- 3.260*	.000
NOS 2	35	4.06	0.59	4.11	0.75	- 4.585*	.000
NOS 3	35	4.36	0.49	4.29	0.64	- 4.529*	.000
NOS 4	35	4.19	0.43	4.14	0.53	- 1.576*	.000
NOS 5	35	4.32	0.44	4.36	0.59	- 1.527*	.000
NOS 6	35	4.27	0.58	4.39	0.81	- 4.979*	.000
NOS 7	35	4.42	0.44	4.50	0.56	- 7.230*	.000
Overall	35	4.28	0.50	4.29	0.61	- 3.712*	.000

*$p < .05$

derstanding following the group of the scientific community (IV) with a score of 5 in six aspects: NOS 1, NOS 2, NOS 4; NOS 5, NOS 6, and NOS 7. For NOS 3, six students (85.73%) have an understanding in accordance with the group of the scientific community (IV) and one student (14.27%) has an understanding in accordance with the adaptive phase (TV) (Safkolam et al., 2024).

Meanwhile, based on the interview results after one month class, all students (100%) are classified as an understanding following the group of the scientific community (IV) in six aspects: NOS 1, NOS 3, NOS 4, NOS 5, NOS 6, and NOS 7. For NOS 2, two students are classified as an understanding following the group of the adaptive phase (TV) (14.28%), as shown in Table 5.

Table 5. Percentage of students' understanding of the nature of science interviewed after one month of study

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

For interviews on understanding the nature of science after class and after one month of study, we gave the extract of interviews in each feature, as shown in Table 6.

Aspect of NOS	Interview results after class	Interview results after one month
NOS 1	"Scientific knowledge can change if scientists have verifiable empirical evidence. There is evidence strong enough to refute the old knowledge that there are eight planets; for example, Thomson's theory refutes Dalton's theory. Because Dalton could not explain the questions that arose. As a result, Dalton's theory was immediately dismissed. This shows that scientific knowledge can change." (Student 4)	"As technology advances, scientists' discoveries become possible when new knowledge is available with empirical evidence to explain it. This causes old theories to be refuted." (Student 4)
	"As technology advances, discoveries by scientists or the invention of new things, such as telescopes, become possible. In the past, humans could only see small stars with the naked eye. Humans will be able to see more stars beyond Earth. Scientific knowledge can change. When new knowledge with empirical evidence can be explained, it is acceptable to disprove old theories, such as Dalton's atomic theory that atoms are solid spheres. Scientists like Thomson conducted experiments and had empirical evidence. It can be explained that it is more reliable than Dalton. As a result, Dalton's theory was obliterated. This put Thomson's ideas in place of Dalton's. This shows that science knowledge can change." (Student 14)	"Science in the future is constantly evolving and may change if new knowledge is discovered and empirical evidence can refute old evidence, due to the advancement of science and technology today. Science is constantly changing." (Student 14)

Aspect of NOS	Interview results after class	Interview results after one month
NOS 2	"Science must have verifiable evidence because in order to know whether or not science exists, we must explain how it was discovered to confirm what we know, what we actually found, such as the discovery of dinosaur bones. As a result, scientists rely on creativity. Imagination lets us know that dinosaurs really existed in the past. Fossils as empirical evidence." (Student 2)	"Obtaining scientific knowledge must be based on evidence and can be explained because evidence will make knowledge acceptable. For example, when we experiment to determine the antioxidant activity of soursop, the results of the experiment will be proven." (Student 2)
	"Scientific knowledge must have verifiable evidence to show that the evidence obtained can be confirmed as something discovered, so as to provide credibility to others." (Student 17)	"Scientific knowledge must be enriched with verifiable empirical evidence. This allows people in society to gain credibility in their findings and be able to verify them. For example, the discovery of dinosaur remains explains the origin of dinosaurs in the past." (Student 17)
NOS 3	"The acquisition of scientific knowledge has a variety of methods. The creativity and imagination of scientists will require various methods to acquire scientific knowledge. Example: Jabir studied acid-base; Al-Razi had a different approach to Jabir by using the dry distillation method as an experimental method. Ibn al-Haitham used the observation method." (Student 2)	"Scientific knowledge can be acquired only by observation or experimentation. It is not just about observing. Experimentation alone, but also the use of imagination and thinking. For example, by describing the previous land by surveying two areas, it was found that the two areas were so similar that it was possible to conclude that the two areas were previously close to each other, explaining the existence of nuclei in atoms through alpha particles experiment and using imagination to explain them." (Student 2)
	"There are many scientific methods, such as alkaline acidity testing, but there are many methods that can be tested, such as litmus paper, pH meter testing, universal paper testing, and Indicator. In addition to testing, observation survey experiments that rely on imagination and creativity, are also scientific methods, such as Dalton's theory of acquired knowledge. This only requires imagination and creativity. It is not the result of any experimental testing. As for Rutherford, knowledge is gained through experiments. Experiments require imagination and creativity. In addition, Snellius himself did not only use experiments. However, they also used mathematical principles to explain the relationship of light refraction." (Student 12)	"To gain scientific knowledge, various scientific methods a re required, such as observation, opinion, etc. Example: Dalton used imagination and thought, while Ibn al-Haitham observed and experimented with the refraction of light." (Student 12)

Aspect of NOS	Interview results after class	Interview results after one month
NOS 4	"Discovering science or creating innovation has to connect with people in society, such as COVID-19, and we have the technology to create a vaccine to tackle the pandemic. This shows that society influences the work of scientists." (Student 15)	"The starting point for innovation should be related to people's living conditions, such as the COVID-19 pandemic. Scientists must create innovations to treat people in society, such as vaccines, to stop the spread of infection to others. Therefore, innovations must be relevant to people's lives." (Student 15)
	"Some experiments influence the beliefs and thoughts of people in society. This causes resistance from people in society. As a result, experiments are suspended or banned altogether, such as using rabbits in cosmetic experiments or cloning animals, which can be done with many verification processes. However, it is not possible to clone humans to prevent future problems." (Student 17)	"Society and culture influence the work of scientists; for example, in today's society facing the COVID-19 situation, microscopy is considered a technology that will help to determine what type of virus is currently present. This will allow us to expand our scientific knowledge of COVID-19 Omicron. Then, the vaccine will be given to people in the country where it is produced to reduce the COVID-19 epidemic. This can help solve the problems of people's lives." (Student 17)
NOS 5	"The acquisition of scientific knowledge requires observation and opinion. Observation is using one of the senses, which obtains information without us giving an opinion about it. Opinion is information obtained from rational observation with the help of knowledge and experience." (Student 1)	"There is a difference between observation and opinion. Observation uses one or more senses, with information obtained without comment. Opinion is a rational explanation of information obtained from observation using knowledge and experience. For example, scientists observe the remains of an organism by observing its shape and describing its form (observation), then use the observations and existing experience to determine what form it might take." (Student 1)
	"Observation is simply the use of one of the senses to explain information, but opinion is the explanation of information obtained through observation and experience. For example, if we see a sharp curve, we will explain that it looks like this, but if there is an opinion, we will use experience to help; for example, this fossil is probably a bird. This will show that science is based on observation and opinion." (Student 14)	"Scientific knowledge requires observation and opinion. In any educational process from the work of scientists, if we use observation alone, we can only observe what we see. However, if opinion comes, it can explain more about what we see and have acquired. Opinions also have experience and prior knowledge to explain them. Example: Seeing a car in a river. If the observation is that there is a car, water, and stones, but if it is an opinion, we may agree that the car had an accident or fell into the canal." (Student 14)

Aspect of NOS	Interview results after class	Interview results after one month
NOS 6	"Scientific knowledge requires creativity and imagination in every process. For example, for a scientist to experiment, he/she must plan and design the experiment to see more clearly what he/she is doing. For example, designing a model of an atom requires creativity and imagination to see clearly what we are doing." (Student 5)	"Imagination and creativity are part of what we use to develop scientific knowledge. The work of scientists relies on imagination and creativity at every stage, such as Mendel's experiments, where he used imagination and creativity, where he used peas to burn the stove while studying genetic traits. He took peas and studied them by observing them and imagining how they would look if they studied their genetic characteristics and used his imagination to design experiments." (Student 5)
	"Scientific knowledge requires imagination and creativity, such as discovering fossils in each place. When the pieces are complete, we want to know what they are; they need to be pieced together, which requires imagination and creativity to become various shapes. This demonstrates imagination and creativity as a means of acquiring knowledge of science itself." (Student 9)	"Scientific knowledge requires imagination and thinking. Scientists use imagination and creativity at every stage of their scientific work; for example, explaining the Big Bang theory relies on imagination and creativity until they acquire scientific knowledge." (Student 9).
NOS 7	"Science and technology will be developed or invented to respond to people in society; for example, cars are built to respond to human journeys and problems in society; we will bring scientific knowledge to solve them and maybe use technological innovations. For example, COVID-19 is caused by a virus mutation, causing a huge pandemic in society. As a result, scientists have had to invent antiviral drugs, resulting in new knowledge and innovations such as ATK in virus detection." (Student 2)	"Science knowledge can be used to develop technology over time. The more advanced technology, the more comfortable people will be in society. For example, in the COVID-19 situation, when we know science, we can create vaccines, which are new technologies to treat people in society and reduce the mortality rate and the number of people infected with COVID-19." (Student 2)
	"Society influences the work of scientists. When the conditions of life of people in society are in trouble, scientists have to help solve social problems by applying scientific knowledge to help solve those problems. While scientists must use scientific tools, they must have technology involved in their inventions to create scientific equipment to help expand scientific knowledge and facilitate solutions for people in society. For technology to produce scientific devices or other inventions that facilitate society, scientific knowledge must also be applied, such as in COVID-19. A global pandemic has caused scientists to find the virus and create a vaccine. Scientific equipment and new technology make it possible to create convenient vaccines and ATK machines and solve problems for people in this setting." (Student 16)	"The problems in our society will be solved by scientific knowledge and may be used to innovate new technologies. For example, COVID-19 is caused by a virus mutation, causing a huge pandemic in society. As a result, scientists have had to invent antiretroviral drugs, resulting in new knowledge and innovations such as ATK in virus detection." (Student 16)

Based on the results of the questionnaire and interview on understanding the nature of science, after one month of study with a series of activities using the inquiry process combined with the reflection and history of scientists, it is found that most students are classified as understanding following the scientific community resolution. The number of students classified in the adaptive understanding (TV) group and the non-conforming understanding (NV) group in the scientific community has decreased significantly from before studying all the characteristics of the nature of science. The results of both questionnaire and interview are consistent.

Based on the responses to the questionnaire, students had a statistically significant average score of .05 on understanding the nature of science after a one-month hiatus. This may be due to the learning activities developed focusing on learning management and inquiry consisting of 5 stages: interest stimulation stage, exploration and search stage, explanation and conclusion stage, knowledge expansion stage, and evaluation stage, where learners will get hands-on learning experience, have the opportunity to explore, investigate, search, and experiment on their own. This creates new knowledge independently (Assem et al., 2023; Haidar et al., 2020). The activity emphasizes the process of inquiry. Students get to explore information and learn about the scientific process, allowing students to gain hands-on experience, discover scientific principles, practice scientific processes, and use scientific methods to solve problems among peers (Machado et al., 2023). This allows students to learn in an independent setting. This results in greater motivation and stimulation for learning and leads to the development of an understanding of the nature of science (Khisfe, 2020; Özden & Yenice, 2022). As learners work and discuss together, they develop their scientific reasoning skills by exchanging comments and listening to others's opinions logically (Fan, 2023; Rodríguez Ortega et al., 2019). This atmosphere allows students to examine their understanding and correct misunderstandings in class, leading to changes and improvements in students' understanding of the nature of science (Cofré et al., 2019; Stadermann & Goedhart, 2021).

In addition, all learning activities involve discussion between the instructor and the learner using questions that indicate and reflect on the nature of science (Metin, 2022; Witucki et al., 2023). Previous research has shown that learning management that promotes a good understanding of the nature of science indicates and reflects the nature of science (Hrisa & Psillos, 2022; Mesci, 2020; Namgyel, 2023). This aligns with Mulvey and Bell (2017) that after conducting explicit and reflective learning about the nature of science for ten months, teachers' understanding of the nature of science remained correct.

One reason may be that the learning activity series consists of worksheets. The video and photo cards show the acquisition of scientific rules and theories of scientists, and some questions reflect the natural features of science that students have to answer together in class. This is a question that reflects the natural features of science. The learning materials used to organize learning activities allow students to learn the history of science discoveries by scientists. This will demonstrate the change. The development and acquisition of scientific knowledge by scientists leads to the learner's understanding of the nature of science, especially in social and cultural features that influence the work of scientists. The scientific method is varied, with no fixed steps (Ayık & Costu, 2020; Nelson et al., 2019). Students learn the history of scientists. Reflecting on the nature of science together with the history of science will result in an understanding of the nature of science (Herman et al.,2019). In addition, learning materials train students to observe and comment, and knowledge encourages learners to understand the characteristics of science through observation and opinion (Kim & Park, 2018).

Based on the results of the research after one month of study, it is still found that two students are classified as the Adaptive Understanding (TV) group (14.28 %) in NOS 2. This is consistent with the research results of Leblebicioglu (2019). Research on learning perseverance through science camp activities on the nature of scientific inquiry finds that students who pass science camp activities on the nature of scientific inquiry experience a decrease in learning perseverance about the nature of science. This may be due to the learning activities that researchers conducted, which emphasized identification and reflection to make learners understand that scientific knowledge must be evidence-based and verifiable but lacked explaining to learners that the work of scientists sometimes not only relies on experiments to obtain verifiable empirical evidence but also require imagination and creativity. Therefore, sometimes scientific knowledge does not always require evidence. According to Khishfe (2023), one of the factors contributing to the change in understanding the nature of science stems from the instructor. Even if an experiment mimics the work of scientists and gives students hands-on experience, it does not mean that students can understand the nature of science through this experience. This is consistent with Ozgelen et al. (2013). If, in learning through scientific experiments, students identify and reflect on the nature of science, this feature will give students a more accurate understanding of the nature of science and the fact that science knowledge is evidence-based and verifiable.

This study implies that a series of inquiry-based learning activities combined with reflection and the history of scientists can make preservice science teachers persistent in learning to understand the nature of science. Identifying and reflecting on the nature of science is involved during teaching so that they have a correct understanding of the nature of science. The history of a scientist will help students understand the work of scientists, especially due to the influence of society and culture. The work of scientists and scientific knowledge can change. Instructors can incorporate profiles of scientists into science subjects, such as the history of Snellius and the history of Ibn al-Haitham, for example, in teaching physical science or physics subjects. In addition, a series of learning activities can be further developed into a learning management model or workshop course to promote students' understanding of the nature of science. It also benefits science teaching and teachers who teach in such courses. Science teaching for university students and graduates who will apply it should study the handbook and understand the nature of science and all its natural features so that science can be meaningful and long-lasting in learning. Communicating science logically and having a positive attitude towards science leads to knowing science, which is an important goal of science education (Cullinane & Erduran, 2023; Nuangchalerm et al., 2024).

CONCLUSION

This study investigates the learning persistence of preservice science teachers learning with a set of activities. The learning uses an inquiry process combined with reflection and the history of scientists. The results show that after one month of learning, the students understand the nature of science, which is similar to all science attributes. Only a few students fall into the transitional view understanding (TV) category on the feature that science knowledge should be evidence-based and verifiable, indicating that inquiry-based learning activities provide opportunities for students to play a collaborative role. The hands-on and independent practice has a positive effect on improvement. Understanding the nature of science and its indications results in discussion, exchanging ideas, and assessing understanding of the nature of science through activities. In the gallery walk, students and teachers summarize and reflect on the nature of science encountered in learning activities. In addition to using the history of scientists in learning activities, students can also capture their knowledge of the nature of science.

The limitation of this research is that the learning activities developed this time are designed for the target group of preservice science teachers and can only represent a small proportion of preservice teachers from the country. Therefore, demographics and samples should be collected comprehensively. However, the knowledge gained can serve as a teaching guide for science teachers to apply in their classrooms or teaching contexts so that students understand the NOS correctly.

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