

Pre-service Science Teachers' Understanding of the Nature of Science: An Examination and Implications for Further Development

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Abstract

This study aimed to examine the understanding held by pre-service teachers of science concerning the nature of science (NOS), and subsequently improve any misconceptions that were found through follow-up workshops. Ninety-four participants were purposively selected and completed open-ended questionnaire to assess their understanding of the NOS. The instrument consisted of seven aspects of NOS. The findings were then classified into three categories: informed, intermediate and naïve. Those who fell in the naïve category then participated in follow-up workshops. Prior to the workshop, these participants (10% out of the total) were interviewed for more information about their understanding of NOS as a basis for organizing follow-up workshops. Subsequently, three workshops were conducted and a post-workshop questionnaire was distributed to see if there were changes in their understanding. The findings from this study illustrate how students, in spite of receiving instruction on pedagogical content and approaches, may hold different perspectives about subject content. This study also provides an example of how a teacher preparation program may carry out small-scale research that will benefit both the teacher educator and the pre-service teachers.

Keywords: *Nature of science, student teachers, interpretive paradigm*

Introduction

Nature of Science (NOS) has become a significant issue in the teaching of science, as it can mean delivering successful teaching of science, as well as an appropriate understanding of scientific matters (Lederman, 1992; McComas, Clough, & Almazroa, 1998; Kampourakis, 2016; Clough, 2018). It is assumed that learners who understand the nature of science (NOS) are more likely to develop plausible knowledge in science concepts (Clough, 2018). This type of knowledge is important, especially for a knowledge-based society where global citizens need to understand the NOS and technology in a rapidly changing world. More than this, NOS is also an important learning concept as it promotes the development of critical thinking, supports an inquisitive attitude, guides problem-solving through systematic thinking, and also encourages the use of evidence-based methods to make judgments (Lederman, 2013).

While NOS is considered an integral element in the science curriculum, its significance may not be seen in the ways in which pre-service science teachers (PSSTs) are prepared through teacher training programs and institutions. This may be due to the emphasis of knowledge building and the preparation for being a teacher, which places a heavy emphasis on knowing information, rather than developing and processing knowledge about science (Faikhamta, 2013), as well as developing other skills pertinent to the professional life of a teacher (see Hume & Berry, 2011, 2013; Bertram & Loughran, 2012 for examples). In Thailand, this has been a significant issue that some researchers have attempted to address (see Yuenyong, 2013). Hence, to ensure that PSSTs are prepared well to deliver scientific content in an appropriate manner, they should receive explicit pedagogical instruction, as well as encouraged to develop a critical understanding of NOS. This would potentially translate into a better account of how science is connected to their real world (see Yuenyong, 2013).

Taking this into account, the current study aims to examine the understanding of the NOS among fourth-year students majoring in science education. This study was akin to action research, wherein the teacher educator, who is the primary researcher, gleans the perspectives of PSSTs regarding the conceptualization of NOS, which then serves as a foundation for follow-up workshops, with the intent to improve PSSTs' views on NOS. Furthermore, it is hoped that this study can illustrate a current

understanding of NOS held by PSSTs, as well as a way to address those potential challenges. This may serve as a catalyst for other teacher education programs to consider.

Nature of Science: Considerations for Science Pedagogy

The word ‘science’ is derived from the Latin word *scientia*, which means “knowledge”. That is the reason why people tend to look at science as a subject seeking for knowledge. This may also be the reason why some science instructions are based on remembering content. Current pedagogical approaches, however, have abandoned such instructional methods. It is common today to find science instruction comprised of a combination of scientific inquiry processes. According to The American Association for the Advancement of Science (AAAS), scientific inquiry processes can be separated into three types. They are scientific world view, scientific inquiry and scientific enterprise (Schwartz, Lederman, & Crawford, 2004).

This study concerns the scientific inquiry process, because the nature of science (NOS) is considered the base of science knowledge. An overview of scientific inquiry was summarized by Liu and Lederman (2007); it is presented below as follows:

- 1) Processes of the natural world are explainable through use of technology, information and tools at a particular moment to describe the recursive nature of the phenomenon. However, this explanation can later be changed if there are new questions and ways of looking for evidence.
- 2) Scientific knowledge can change depending on new investigation from an emerging issue. There is no absolute truth in science because innovative ways of seeking for up-to-date data can bring people to understand more about natural phenomenon.
- 3) Scientific knowledge is durable. It is true that some scientific ideas are so well established and supported by various evidence that they are unlikely to be completely overturned. However, even these established ideas are subject to modification based on new evidence and perspectives. Furthermore, at the cutting edge of scientific research — areas of knowledge that are difficult to represent in introductory textbooks — scientific ideas may change rapidly as scientists test out many different possible explanations in an attempt to test the accuracy of current knowledge.
- 4) Hypotheses, theories, and laws are all scientific explanations that are somehow related, but there are some significant differences. *Hypotheses* are explanations that are limited in scope, applying to a rather narrow range of phenomena. The term *law* is sometimes used to refer to an idea about how observable phenomena are related, but the term is also used in other ways within science. *Theories* are deep explanations that apply to a broad range of phenomena and that may integrate many hypotheses and laws.
- 5) Science cannot answer every single question about the world, especially ones related to supernatural phenomenon or things that cannot be proven by scientific methods.
- 6) There are complex processes in scientific inquiry including logical, empirical evidence, imagination, and inventiveness. This means science is evidence-driven matter requiring both logic and imagination.
- 7) There is a distinction between science and technology, in that science focuses more on building knowledge, while technology emphasizes the use of knowledge to improve life’s convenience.

Teachers’ View about Nature of Science

It has been established that a teacher’s perception towards content will have a bearing over how this content is understood and taught in the classroom. This is also a belief that affects science educators (see Hofstein & Lunetta, 2003 for example; Liu & Lederman, 2007).

Various studies in different cultural contexts have accounted for how beliefs or perceptions towards scientific knowledge affect pedagogy. For instance, in the study by Schwartz, Lederman, and Crawford (2004), PSSTs were found to approach scientific experiments differently. While there were

participants who were open to question research procedures they were familiar with, there were also those who were not critically engaged in the process. This, according to the researchers, may restrict a science teacher's professional development if that teacher does not consider known or familiar knowledge worth questioning. On a similar vein, Liu and Lederman (2007) found that among PSSTs, there were those who were more willing to accept the tentative nature of knowledge, while there were those who were rigid in their view towards science.

In order to impart the correct assumption about scientific knowledge and to encourage a spirit of continued discovery, it is then vital that PSSTs, as well as other subject and skills teachers, develop inquiry-based skills in their students. For science education, this would include helping students acquire suitable strategies to work with scientific knowledge: for instance, to look at the learning of science as a process of inquiry, instead of memorizing a list of facts (e.g. McComas, 2000). Studies have indicated that PSSTs may develop this skill through collaborative design of science courses with in-service science teachers, (e.g., Hume & Berry, 2013), or by taking a sociocultural perspective on science education. For example, Lemke (2001) points out how in-service science teachers and PSSTs should consider their students' identity and cultural values when teaching science. This will not only encourage participation from students, but it will also give students the chance to critically evaluate information presented to them as empirically sound.

In Thailand – the broader context where this study was carried out – studies have been carried out that illustrate how science pedagogy takes on an NOS approach, and science teachers' understanding and perception of NOS. These findings have indicated that while there may be a general conception that learning that takes place in the Asian culture may be memory-based, students are actually able to adapt a more critical approach to learning science (as well as technology) if they are guided appropriately (Tucksanunklahan & Yuenyong, 2012). This may be true across the nation. As reported by Yuenyong (2013), different research and projects on the development of scientific literacy in Thailand are ongoing, indicating that the nation is actively involved in developing the training of PSSTs, especially after regional and global results indicated low scores of scientific knowledge among students. Nonetheless, the challenge of a misconstrued idea of NOS still remains. This may be seen through Sangsa-ard and Thathong's (2014) study, which found that slightly over half of their participants surveyed (63.3%) had a partially accurate knowledge about NOS. The remaining 32.7% held an informed view of NOS, while 6.6% had a misconception about NOS. This finding, as well as the efforts set out by different entities to improve science teachers' approaches towards science pedagogy and understanding, brings about the assumption that the professionalism of science teachers and PSSTs needs to be further developed.

Methodology

Context

In Thailand, the NOS concept was introduced into the curriculum in 1975 to promote learning through scientific methods. This concept has been retained until today, as seen through the position of NOS in the current national curriculum. For example, the 2001 national science curriculum was designed to present content about NOS as a major component (Strand 8) in order to promote students' knowledge about the link between science, technology, society, and environment. The focus of this strand is "Nature of Science and Technology: scientific processes; investigation for seeking knowledge, problem-solving, and scientific mind" (MOE, 2001, p.8).

This study was conducted at the Faculty of Education, Sisaket Rajabhat University. The Faculty houses a teacher training institution which aims to produce future teachers to serve schools throughout Thailand. It is the main goal of the Faculty to prepare learner-sensitive educators with the knowledge, skills, and dispositions to contribute to society. The students in this Faculty spend four years completing both compulsory and elective courses according to their major. Then, they have to participate in a one-

year practicum to experience actual teaching in the real world before graduating.

Taking into account the broader national aspiration for science education, it is expected that PSSTs at the research site will undergo training which will make them perceptive towards ways in which scientific knowledge may be taught. This may be further problematized considering the social environment of the research setting, where knowledge may be understood in light of the authority of a teacher, as well as the beliefs about religion and culture held by the Thai community (Yuenyong & Narjaikaew, 2009).

Participants

There were 94 participants involved in this study. All of them were fourth-year PSSTs. At the time of the research study, they had completed all the compulsory courses, including a class taken in their sophomore year called “History and Nature of Science”. This class aimed to promote students’ understanding about NOS and how to apply it in various teaching contexts.

Research Procedure: Examining Participants’ Understanding about NOS

The participants’ understanding of NOS was gauged through an open-ended questionnaire. The questionnaire was adapted from Lederman, Abd-El-Khalick, Bell, and Schwartz’s (2002) Views of Nature of Science Questionnaire (VNOS). The VNOS is structured as an individual interview that is capable of providing meaningful assessments of a person’s NOS views. In other words, the open-ended instrument allowed the participants to freely express their ideas regarding the NOS. Some of the topics asked in the modified VNOS are presented in Table 1.

Table 1. Some Topics in the Modified Views of Nature of Science Questionnaire

What is science?
What is an experiment?
What is the relationship between science and social/cultural values?
What is the difference between an opinion and a scientific piece of information?

Data Analysis

Participants’ responses were then classified into three groups, which were the naïve view, intermediate view and informed view. These groups were categorized according to the linkage between science association ideas and the PSSTs’ responses to the modified VNOS, similar to the study of Lederman, Abd-El-Khalick, Bell, and Schwartz (2002). Specifically, content analysis was used to categorize the participants’ responses. The guide for the content analysis was adapted from Sangsa-ard and Thathong (2014), which is as follows:

- 1) *Not categorized*: this type of answer was exempted from the analysis: for example, if a question asked about how scientists use evidence to categorize species, but students answer by describing what *species* means. This type of answer was not counted as analysable data, so it does not appear in the results section.
- 2) *Naïve view* refers to answers that are not related to scientific association concepts: for example, when students think that experiments are vital for scientific knowledge, even it is not always true that scientific experiments are the only way to develop scientific knowledge. In fact, collecting data deductively, inductively and evidence-based approaches can be included.
- 3) *Intermediate view* refers to student answers that are somewhat related to the idea of scientific association: for example, when students think that scientists use creativity and imagination in working, but they might think that the scientists only use in planning stage. In fact, creativity and

imagination can be integrated in all scientific inquiry from the beginning until the end.

- 4) *Informed view* occurs when students' answer are accurate according to scientific association: for example, students think that science is an evidence-based matter. This is different from other subjects such as religion, because it cannot explain extraordinary phenomenon.

Follow-up Workshops and Post-Workshop Questionnaire

The results of this questionnaire then guided the allocation of PSSTs into groups, with groups that needed further guidance on an inquiry-based understanding of NOS being directed to participate in a series of follow-up workshops. The themes addressed during the follow-up workshops were grounded in the results of the responses to the adapted VNOS.

Findings

Table 2 indicates the different categories of views among the 94 participants. It was noted that more than half of the participants hold a naïve to intermediate view. Some items for which a majority held a naïve view were Items 3, 5, and 7. Item 3, which asked about the importance of experiments in developing scientific knowledge, saw PSSTs' indicating their belief that experiments are very important in scientific inquiry. This is justified by stating that other subjects do not have this approach in discovering knowledge. Item 5, another item with a naïve view, saw many PSSTs reporting that law and theory come from proven hypotheses. When more corroborating evidence is found, and rigorous experiments are

Table 2. Results of Pre-Service Science Teachers' Understanding about Nature of Science

Questions	Participants' View			Total
	Naïve	Intermediate	Informed	
1. Meaning of science	14 (15%)	58 (62%)	22 (23%)	94
2. Meaning of experiments	8 (9%)	74 (79%)	12 (13%)	94
3. Importance of experiments in developing scientific knowledge	90 (96%)	2 (2%)	2 (2%)	94
4 Pre-existing theory in developing scientific knowledge	16 (17%)	62 (66%)	16 (17%)	94
5. Differences between law and theory	45 (48%)	49 (52%)	0 (0%)	94
6. Changes in theory	10 (11%)	76 (81%)	8 (9%)	94
7. Empirical evidence in interpreting scientific knowledge	38 (40%)	46 (49%)	10 (11%)	94
8. Imagination and creativity	4 (4%)	84 (89%)	6 (6%)	94
9. Scientific interpretation	30 (32%)	34 (36%)	30 (32%)	94
10. Linkage between science and society	6 (6%)	78 (83%)	10 (11%)	94
Total	261 (27.7%)	563 (59.9%)	116 (12.4%)	94

Carried out, a theory can subsequently be accepted as law. In fact, the term *law* is sometimes used to refer to an idea about how observable phenomena can be related; nonetheless, the term is also used in other ways within the field of science, which the PSSTs may have misunderstood. For instance, theories can be explanations that apply to a broad range of phenomena and that may integrate many hypotheses and laws. Finally, Item 7, with a total of 38 PSSTs holding a naïve view, saw responses that reflected a belief that scientific ideas do not change. This belief is perpetuated by the claim that PSSTs have never seen any changes in information found in textbooks. Nonetheless, it is actually common that scientific ideas change rapidly as scientists test out many different possible explanations, trying to figure out which are the most accurate.

Follow-up Workshops

After identifying the problematic issues from the questionnaire and the semi-structured interview, follow-up workshops were prepared in order to rectify PSSTs' misconceptions about matters that scored in the naïve category. Prior to the follow-up workshops, a deeper understanding of the challenges faced by PSSTs was gained by requesting some of them to elaborate their perceptions. There were 10% of the participants with the naïve view who were interviewed. From these ad-hoc interviews, three workshop themes were selected. These three workshops were: 1) varieties of coloured paper: investigating different ways to inquire about knowledge apart from solely relying on conducting experiments; 2) the moon phase: various methods of seeking scientific knowledge; and 3) fingerprints: focusing on natural phenomenon as a way to seek scientific knowledge. These themes are further elaborated in Table 3.

Table 3. List of Workshops to Develop Problematic NOS Understanding

Workshop Theme	Purpose	Procedures
1. Variety of colored papers	Investigating different ways to inquire knowledge by not focusing only on experiments	Selecting different colored papers as the way to lead to learners' knowledge, before moving to how to differentiate between law and theory
2. Moon phase	The methods to seek scientific knowledge are varied.	Using different strategies to figure out the moon phase in order to see the various ways of identifying explanations of a phenomenon
3. Fingerprints	Scientific knowledge can be obtained from natural phenomenon, through systematic data collection and analysis.	Figure out how to differentiate people' fingerprints by using scientific-inquiry methods

These workshops were carried out by the primary researcher, with help from a colleague. After the workshops, the PSSTs' then completed the same questionnaire used in the first step before the follow-up workshops. However, the content asked was limited to the three problematic items with the most naïve views. The results are shown in Table 4.

From the results, it is noticeable that there were differences between the perceptions of students prior to the workshops and after the workshops were concluded. The levels of differences are noticeably varied, too. This is perhaps due to the types of workshops that were organized, which teacher educators need to bear in mind.

Table 4. Changes in View: Pre-workshop and Post-workshop

Questions	Participants' Views					
	Naïve	Pre-workshop Intermediate	Informed	Naïve	Post-workshop Intermediate	Informed
3. Importance of experiments in developing scientific knowledge	90(96%)	2 (2%)	2 (2%)	80 (85%)	12 (13%)	2 (2%)
5. Differences between law and theory	45(48%)	49 (52%)	0 (0%)	40 (43%)	54 (57%)	0 (0%)
7. Empirical evidence in interpreting scientific knowledge	38(40%)	46 (49%)	10 (11%)	56 (60%)	38 (40%)	0 (0%)

Final Remarks

From this study, there were several lessons learnt for different domains. Let us first consider the teacher preparation domain. In this particular domain, lessons addressed the issues of PSSTs' perception towards NOS, the value of providing explicit instruction to PSSTs on ways to teach science, and the value of teaching science in light of students' environment. First, it was observed from conducting workshops that examining PSSTs' perception, whether through open-ended surveys or other forms of self-report, might not be sufficient to help teacher educators gain an understanding about their students. For a more comprehensive account of PSSTs' perception, it would be viable to conduct working opportunities, such as those seen through the workshops organized in this study. As exemplified by Hume and Berry (2013), through the completion of collaborative tasks, assumptions about teaching held by teacher educators and pre-service teachers can be refuted or solidified, and teaching principles can be improved.

Another lesson learned is that while PSSTs may have spent years taking the same courses to prepare for their future careers as science educators, it is not safe to assume that they have acquired the necessary skills to impart knowledge regarding current understandings of NOS. As indicated earlier in this study, explicit instructions and active reflections must be done by PSSTs themselves so as to develop appropriate pedagogical skills and epistemologies for the successful organization and delivery of science lessons. Furthermore, another noteworthy issue emergent from this study is that the NOS should not be restricted in its own professional domain. As argued by past studies, NOS needs to be taught in line with other aspects of human life, such as cultural values and societal expectations (Lemke, 2001; Schwartz, Lederman, & Crawford, 2004; Yuenyong, 2013; Kampourakis, 2016).

In the teacher educator domain, this study exemplified that carrying out research during the term could be fruitful. The systematic analysis of pre-service teachers' perceptions, or other aspects relevant to the teacher professionalism, can provide a basis for strengthening teacher preparation programs and pre-service teachers' preparedness, as well as their positive disposition towards certain pedagogical principles (Rehmat & Bailey, 2014). From a teacher educational research perspective, what this study presented is the possibility to examine pre-service teachers' changing perceptions through tasks that aim to deconstruct preconceived notions about a subject matter or pedagogical approach. Perhaps for future research, continued observation of pre-service teachers' performance in class, as well as through iterative reflection, could provide an elaborated account of potential changes in teaching epistemology. Alternatively, pre-service teachers' teaching journeys can be traced after transitioning into in-service. This would be interesting to examine, especially in the context of this study, where religious and cultural values still play a significant role in education.

In summary, this study is an example of how science teacher trainers can develop pedagogical content knowledge through a small-scale study. Specifically, this includes knowing how students work with subject-specific concepts in terms of misconceptions and misunderstandings, and how to incorporate workshops to help students develop perceptions towards teaching. Furthermore, issues which science teachers in the today's society need to take into account when preparing science lessons were mentioned. By incorporating the principles of the NOS into their pedagogical activities, there is an increased possibility for students to develop appropriate scientific thinking.

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References

Bertram, A., & Loughran, J. (2012). Science teachers' views on CoRes and PaP-eRs as a framework for articulating and developing pedagogical content knowledge. *Research in Science Education*, 42(6), 1027-1047.

- Clough, M. (2018). Teaching and learning about the nature of science. *Science & Education*, 27(1-2), 1-5.
- Faikhanta, C. (2013). The development of in-service science teachers' understandings of and orientations to teaching the nature of science within a PCK-based NOS course. *Research in Science Education*, 43(2), 847-869.
- Hofstein, A., & Lunetta, V. (2003). The laboratory in science education: Foundations for the twenty-first century. *Science Education*, 88(1), 28-54. Retrieved from <http://gpquae.iqm.unicamp.br/gtexperimentacao.pdf>
- Hume, A., & Berry, A. (2011). Constructing CoRes—a strategy for building PCK in pre-service science teacher education. *Research in Science Education*, 41(3), 341-355.
- Hume, A., & Berry, A. (2013). Enhancing the practicum experience for pre-service chemistry teachers through collaborative CoRe design with mentor teachers. *Research in Science Education*, 43(5), 2107-2136.
- Kampourakis, K. (2016). The “general aspects” conceptualization as a pragmatic and effective means to introducing students to nature of science. *Journal of Research in Science Teaching*, 53(5), 667-682.
- Lederman, N. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching*, 29(4), 331-359.
- Lederman, N. (2013). Nature of science: Past, present, and future. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of Research on Science Education* (Vol. 2; pp. 845-894). New York: Routledge.
- Lederman, N., Abd-El-Khalick, F., Bell, R., & Schwartz, R. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, 39(6), 497-521.
- Lemke, J. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching*, 38(3), 296-316.
- Liu, A., & Lederman, N. (2007). Exploring prospective teachers' worldviews and conceptions of nature of science. *International Journal of Science Education*, 29(10), 1281-1307.
- McComas, W., Clough, M., & Almazroa, H. (1998). The role and character of the nature of science in science education. In W. F. McComas (Ed.) *The Nature of Science in Science Education* (pp. 3-39). Springer, Dordrecht.
- McComas, W. (2000). The nature of science in science education: Rationales and strategies. Dordrecht, the Netherlands: Kluwer Academic Publishers.
- Ministry of Education (MOE), Thailand (2001). *Basic Education Curriculum*.
- Rehmat, A., & Bailey, J. (2014). Technology integration in a science classroom: Preservice teachers' perceptions. *Journal of Science Education and Technology*, 23(6), 744-755.
- Sangsa-ard, R., & Thathong, K. (2014). Examining Junior High School Science Teachers' Understanding of the Nature of Science in Chaiyaphum Province, Thailand. *Procedia-Social and Behavioral Sciences*, 116, 4785-4797.
- Schwartz, R., Lederman, N., & Crawford, B. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science Education*, 88(4), 610-645.
- Tucksanunklahan & Yuenyong, C. (2012). An analysis of grade 12 students' technological capability in learning about electromagnetics through science technology and society approach (STS approach). *Procedia-Social and Behavioral Sciences*, 46, 5085-5093.
- Yuenyong, C., & Narjaikaew, P. (2009). Scientific Literacy and Thailand Science Education. *International Journal of Environmental and Science Education*, 4(3), 335-349.
- Yuenyong, C. (2013). Enhancing Scientific Literacy in Thailand. *Global Studies of Childhood*, 3(1), 86-98.