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THE IMPLEMENTATION OF SCIENCE, TECHNOLOGY AND SOCIETY ENVIRONMENT (STSE)-BASED LEARNING FOR DEVELOPING PRE-SERVICE GENERAL SCIENCE TEACHERS' UNDERSTANDING OF THE NATURE OF SCIENCE BY EMPIRICAL EVIDENCE

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ABSTRACT

The objective of this research was to study the outcomes of teaching method based on Science, Technology, Society, and Environment (STSE) in enhancing the nature of science understanding, emphasizing the empirical evidence among 23 pre-service general science teachers at one of Rajabhat Universities in the upper northern region, Thailand. The samples were selected using the purposive random sampling technique from a population of bachelor education program students who enrolled in the second semester in the academic year of 2016. The research instruments consisted of questionnaires and ten learning management plans based on the concept of Science, Technology, Society, and Environment (STSE) emphasizing on empirical evidence covering ten environmental issues in the upper northern region. Such learning managements have steps for students to utilize empirical evidence to create the nature of science understanding. Mean and standard deviation were applied to data analysis, then the results were presented descriptively. The research found that the pre-service teachers had a better understanding of the nature of science after studying with the statistical significance and were satisfied with the implementation of the teaching method.

Keywords: nature of science, nature of science understanding, scientific evidence, Science, Technology and Society Environment (STSE)

INTRODUCTION

The nature of science is considered as the core of scientific literacy, as can be seen in the identification of science in national and international science education programs. OECD Programme for International Student Assessment (PISA) defines nature of science as how scientific knowledge and the degree of confidence are set up for the everyday practices of scientific inquiry and the status of the knowledge claims that are generated; also, the meaning of foundational terms such as data, hypothesis, and theory (PISA 2015; Vayssettes, 2016).

The theoretical framework of the nature of science roots back decades. The American Association for the Advancement of Science defines the understanding of the nature of science as a critical component of science (The American Association for the Advancement of Science [AAAS], 2009). It becomes the vital goal of science learning which is to encourage students to learn scientific concepts, nature of science understanding, create a link between evidence to create explanations of various phenomena, and lead to the creation of various effects to a society based on morality (Ministry of Education, 2017).

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This project aimed to develop science learning to be effective in advancing people's literacy of science, mathematics and technology, research and documentation with more unequivocal evidence of the nature of science, and promote the knowledge of human science. For instance, knowing that science relies on a scientific worldview with the belief that science is not free and is the most objective, but related to individuals and society (Abd-El-Khalick, 2013; Faikhamta, 2013). This idea is in accordance with Clough's (2011) concept that the nature of science helps promote science learning among students since it assists to realize the value of scientific knowledge discovery, create a better understanding of various principles as well as the most essential basis for the nature of science, allow students to seek knowledge on their own, create new knowledge, understand the nature and limitations of science, understand the effect of science including the impact of technology to society (NRC, 1996; NSTA, 1993). As a result, educational scientists perceive the nature of science and determine the integration of science learning to students.

However, the study of related research found that most science teachers, as well as students, had some misconceptions about the nature of science (Lederman, 2013). They perceived that the scientific method must have a fixed sequence. Referring to Lalitanurak & Faikhamta (2011), pre-service teachers had mistakenly thought that scientific knowledge was obtained from scientific methods according to the sequence with specific steps, and the experiment is the only scientific method (Magee & Flessner, 2011). Moreover, Allchin (2014) advocated for the strategy that enables immersions and findings a pathway through a complex environment or a highly integrated system of learning, which is more effective.

The primary purpose of STSE education is to empower individuals by helping them achieve scientific literacy so that people can make decisions about science, technology, and other related topics that influence society (Pedretti & Nazir, 2011; Mansour, 2009; Yager, 1992). The Science, Technology, Society, and Environment (STSE) is an approach that integrates, science, technology, society, and environment which emphasize the connection and interaction among them. It emphasizes learning in authentic inquiry climate for developing understanding, skills, and inquiry, that relevant to the daily life of society, technology, and environment. The students act in both individuals and groups and work with various activities and learning media concerning the current environmental situations or issues (Pedretti & Nazir, 2011). As STSE provides the reflections of various aspects of nature of science, some research results confirm that STSE not only helps the students develop their understanding of nature of science but also encourage pre-service teachers to reflect the nature of science in their classroom (Gathong & Chamrat, 2019). They can design and implement lessons focusing on the development of knowledge, concepts, theories, as well as problem-solving skills (Pedretti & Nazir, 2014). Moreover, in achieving a successful STSE learning management, teachers must act differently in the classroom. The students must be the center of activities, evidence collection to support ideas, data collection procedures, and actions taken for solving problems (Akcay & Yager, 2010; Pedretti & Nazir, 2011).

In this study, the students participated in both individual and group activities with the various kinds of learning materials that are related to the current environmental issues. All materials concerning culture, social, and political context could be employed as a learning source. Thus, the students will recognize and realize the responsibility as a human and find the solutions in everyday life. As reported by Solomon (1993) and Aikenhead (1994) in Yoruk et al. (2009), chemistry learning with STSE-based learning management increased students' learning outcomes. In other words, such learning could cause changes in scientific education, which focus on teaching for the establishment of science and technology in the context of culture, social, and political context.

Science education will help students get to know about issues related to the effects of science on daily life. Thus, they will be aware of the responsibility to find ways to solve the problems (Solomon, 1993). Teaching the nature of science with STSE concept along with the explicit approach intends to assist students and teachers to develop ways of thinking and its philosophy about the generation, validate scientific knowledge, and the nature of resultant knowledge (Abd-El-Khalick, 2012).

This study focused on empirical evidence as a reference to accurate and reliable scientific knowledge, which was obtained from observing natural phenomena. It enabled students to link knowledge to what they faced during the data collection. Moreover, the students could make decisions using a variety of information (Ministry of Education, 2017). Empirical evidence of scien-

tific knowledge is exceedingly crucial because science demands evidence of scientific concepts and empirical evidence to confirm the accuracy (Lederman, 2013).

Teachers possess an essential role in teaching and learning that considers the nature of science (Allchin, 2011; Ministry of Education, 2017; The NGSS Lead States, 2013). In achieving the learning objectives, teachers need to seek for ways and concepts which facilitate students to be able to associate the obtained science knowledge to daily life. Most recent studies in Thailand examine the learning achievement of the nature of science, and there are limited studies that employ the SETS teaching method. Thus, it inspired the authors to examine the STSE-based learning management of the nature of science, focusing on empirical evidence. The objective of this research was to study the outcomes of teaching approach based on STSE in improving the nature of science understanding among 23 pre-service general science teachers in at one of Rajabhat Universities in the upper northern region.

METHODS

The objective of this research was to investigate the outcomes of teaching method based on science, technology, society and environment concepts in creating the nature of science understanding that emphasized empirical evidence. The researchers synthesized the conceptual framework that developed the nature of the science by referring to AAAS (2009) and Lederman & Abell (2014) focusing on the ability to lecture, explain and give examples about important characteristics and principles in developing scientific knowledge. Scientific knowledge must be reliable and empiric, and this should be shown in the learning management plan, which consists of 6 steps as follows: (1) **Step 1:** Awakening Interest; (2) **Step 2** Planning for Searching Answers; (3) **Step 3** Finding Answers Using Empirical Evidence; (4) **Step 4** Reflecting Feedback; (5) **Step 5** Applying Authentic Action and Publishing Results; and (6) **Step 6** Evaluation.

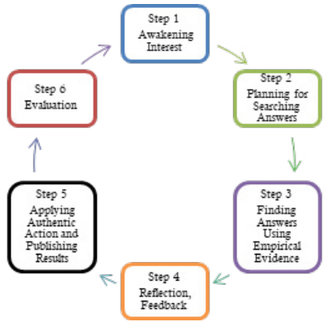

Figure 1. The Steps of STSE Teaching Method (Pedretti & Nazir, 2011)

The explanation of the figure is presented in the following Table 1.

Table 1. The Explanation of Steps of STSE Teaching Methods

Teaching model based on Science, Technology, Society, and Environment (STSE) to create the nature of science understanding by emphasizing empirical evidence				
		Learning Steps		
Concepts and Theories 1.Constructivism 2.Scientific inquiry		**Step 1** Awakening Interest **Step 2** Planning for Searching Answers **Step3** Finding answers using empirical evidence**, which includes** 1.Analyzing and determining problems 2 Searching for evidence 3.Analyzing and synthesizing evidence 4. Applying authentic action and publishing results 5.Evaluation		
Teaching method based on Science, Technology, Society and Environment (STSE) concept	Social System, Roles of teachers and students		Practical principles and supporting system	Measurement and evaluation of the nature of science understanding concerning the issues requiring the empirical evidence
Concepts and Theories		Learning Steps		
		Step 4 Reflection Feedback		
Learning Objective		**Step 5** Applying authentic action and publishing results. **Step 6** Evaluation		

The sample consisted of 23 pre-service teachers who studied in one of Rajabhat Universities in the upper northern part of Thailand and registered the local science course in the second semester of the academic year of 2016. They were selected using the purposive sampling method among the total of 120 populations which cover four subject areas. The tools used in the research consisted of 10 lesson plans based on Science, Technology, Society, and Environment (STSE) teaching method that emphasize empirical evidence covering environmental issues in the upper northern region. The ten learning management plans are informed in the following Table 2.

Table 2. The Learning Management Plans Based on STSE Teaching Method

Sequence	Topic	Empirical Evidence
1	Deteriorated soil	Experiment
2	Breakdown and landslide	Experiment
3	Residues in home-grown garden	Case study
4	Garbage	Data collection and analysis
5	Organic waste	Expert
6	Dust in the air	Case study
7	Smog	Case study
8	Acid rain	Data collection and analysis
9	Water quality	Experiment
10	Energy	Data analysis

All plans passed the validation process by five experts and had trials with a group of students who were not a sample group. Then, they were improved to suit the sample. The lesson plans had 1.00 index of conformity on the composition of the learning management plan. The data were obtained through a one-group pre-test and post-test design research model. The data were then analyzed by comparing the pre- and post-test score of the nature of science understanding. The t-test dependent samples, descriptive statistics using mean, standard deviation were used, and the data were presented descriptively.

The 30 satisfaction items for the assessment of the lesson plans were rated on a 5-point scale and five levels of confidence. The reliability of the satisfaction assessment was calculated using Cronbach's Alpha Coefficient formula. After that, the assessment was computed for the grade level and took that calculated values into satisfaction levels as depicted in Table 3.

Table 3. The Interpretation of the Satisfaction Level

Mean	Level of Satisfaction
1.00 – 1.49	Least satisfied
1.50 – 2.49	Less satisfied
2.50 – 3.49	Moderately satisfied
3.50 – 4.49	Very satisfied
4.50 – 5.00	Most satisfied

RESULTS AND DISCUSSION

The research results were divided into two parts: (1) the outcomes of applying the STSE teaching model on the understanding the nature of science which emphasized on empirical evidence; and (2) the assessment of satisfaction results for the learning management using the STSE teaching model.

The upcoming Table 4 informs the results of the pre- and post-test on the pre-service teachers' understanding of the nature of science which emphasized on empirical evidence.

Table 4. The Analysis Results of the Pre- and Post-Test on the Pre-Service Teachers' Understanding of the Nature of Science

Analysis	N	Scores(full= 30 points)		df	t
		X	SD		
		SD			
Pre-test	23	12.96	1.72	22	16.2441
Post-test	23	21.74	2.16		

According to Table 3, the pre-service general science teachers had an average score of 12.96 and a standard deviation of 1.72. After experiencing the learning with STSE, the average score was 21.74, and the standard deviation was 2.16. The t = 16.2441 showed that the understanding of the nature of science after studying with STSE was higher with the statistical significance of .05.

Table 5. The Outcomes of the STSE Teaching Model on the Learning Management

Step	Learning Management Plan	Outcomes of Learning Management
1	Awakening Interest	69.56% of the pre-service teachers paid attention to the environmental issues around them. They tried to ask questions about the problems that arose by finding out knowledge through various media.
2	Planning for Searching Answers	73.91%of the pre-service teachers used the worked in group, everyone involved in the work, and shared responsible duties.
3	Finding Answers Using Empirical Evidence	91.30% of the pre-service teachers questioned for knowledge and searched for answers to the problems with reasons and effects along with the use of scientific methods. The proposed problem was forest burning and other issues related to air quality. They tried to find information for the past ten years of the amount of air quality until they could create a comparison chart.
4	Reflection and Feedback	The pre-service teachers experienced and exchanged ideas on environmental problems occurred by bringing necessary information about the community or their context to exchange, such as participation of all people.
5	Applying Authentic Action and Publishing Results	Actual practice using the Air4Thai applications for air quality monitoring by the Thai Air Quality Index in order to report hourly and daily data
6	Evaluation	The pre-service teachers evaluated learning management according to actual conditions through peer- and self-evaluation.

The pre-service teachers' understanding on the nature of science was classified into four categories; Informed View, Transition View, Naïve View, and Not Categorized. The comparison of the classification based on the pre- and post-test is displayed in the Table 6 as follows.

Table 6. The Comparison of Pre- and Post STSE-Based Learning on the Nature of Science

Elements of the nature of science	The pre-service teachers' nature of science understanding							
	NC*		NV*		TV*		IV*	
	Before	After	Before	After	Before	After	Before	After
Reference to empirical evidence of scientific knowledge	0	0	5	0	17	3	1	20

Note: IV = Informed view, TV = Transition view, NV = Naïve view, Not categorized = NC

As seen in Table 6, before experiencing learning with STSE-based teaching method, there were 17 pre-service teachers whose nature of science included in the 'Transition View.' There were 5 of them belonged to 'Naïve View,' and there was only one person included as 'Informed View.' After experiencing STSE-based learning, there were 20 pre-service students whose nature of science understanding was categorized as 'Informed View' and 3 of them included in 'Transition View.' The 'Informed View' is the best category among the others. Therefore, STSE-based teaching has helped the pre-service teachers to escalate their nature of science understanding.

The following results are about the satisfaction assessments toward learning management according to the STSE teaching method.

Table 7. The Level of Satisfaction towards Learning Management with the STSE Teaching Method

Elements of Learning Management	X	SD	Level of Satisfaction
Roles of instructors	4.72	0.24	Most satisfied
Roles of students	4.68	0.20	Most satisfied
Learning activities	4.53	0.22	Most satisfied
Learning resources and time	4.49	0.23	Most satisfied
Measurement and evaluation	4.52	0.27	Most satisfied
Benefits	4.61	0.21	Most satisfied
Total	4.59	0.22	Most satisfied

Based on Table 7, the students were satisfied with learning management with the (STSE) teaching method to create the nature of science understanding by emphasizing empirical evidence. The average value was 4.62 and categorized as 'most satisfied.' The highest level of satisfaction was in the roles of instructors followed by the roles of students, benefits, learning activities, measurement and evaluation, and the least was the learning resource and times. In other words, the students were satisfied at a high level and most for all elements.

The researchers conducted the study under the research and development process that is systematic and effective in creating learning management by using Science, Technology, Society, and Environment (STSE) teaching method. The implemented teaching method consisted of six steps; (1) Awakening Interest; (2) Planning for Searching Answers; (3) Finding Answers Using Empirical Evidence; (4) Reflecting Feedback; (5) Applying Authentic Action and Publishing Results; and (6) Integration of Quality Levels of Empirical Evidence. According to the results, the pre-service teachers paid attention to environmental issues; also, tried to ask questions about the problems that arose. The results correspond to Bell et al. (2010) and Lederman et al. (2013) who stated that while studying, science learners use a variety of methods to find knowledge, such as observation, and inquiry.

The core of scientific inquiry is the learning process in which students try to ask and answer questions after analyzing data. Questioning is a fundamental process that affects the students' level of analysis (Kampourakis, 2016; Lederman, 2013; Zeidler & Nichols, 2009). Moreover, questions are a stimulus for students to explore and examine answers. This is parallel to Joyce et al. (2011), who explained that the learning of the nature of science should provide students opportunities to communicate the discussion results.

Furthermore, Hanuscin et al. (2011) argued that teachers who successfully teach the nature of science are those who could adopt new teaching methods that are different from traditional forms, such as practice-oriented teaching, practical science-based teaching, and evidence-based teaching. Besides, it is assumed that learners who understand the nature of science are more likely to develop plausible knowledge in science concepts (Clough, 2018). Yoruk et al. (2009) applied hand-made technology in class for students to learn science, particularly to seek the relationship between Science, Technology, Society, and Environment. Similarly, Solomon (1993) stated that STSE oriented to life problems. Thus, it connects college and family life and at the same time raises awareness of environmental problems.

The research results revealed that the pre-service teachers had a better understanding of the nature of science after studying with STSE-based learning management which focused on empirical evidence, with a significance of .05. In addition, such learning focused on enabling students to learn science by using the inquiry process, which led to decision making and problem-solving (Ministry of Education, 2017). Moreover, the use of STSE-based learning has been proven to enhance 86.95% of the pre-service teachers' understanding of the nature of science. Besides, the students were more flexible in performing contextual activities following the lesson plan.

CONCLUSION

The implementation of STSE concepts by emphasizing empirical evidence has improved the pre-service general science teachers' nature of science understanding. Furthermore, the students were satisfied with the use of the teaching method at the highest level. Emphasizing empirical evidence is one issue of the nature of science, hence, teachers should train students to identify scientific evidence and create explanations from evidence in order to allow students to develop a deeper understanding of the nature of science.

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