

Research Article

The Nature of Science in New Science Learning Indicators of Thai Basic Education Core Curriculum: Documentary Research

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ABSTRACT

According to the revision of Thai science curriculum, the nature of science (NOS) learning strand which used to be explicit was implicitly embedded in learning indicators of all science learning strands. The purpose of this study is to analyze concepts of NOS integrated in learning indicators of science learning strands revised in B.E. 2560 (A.D. 2017) in the Basic Education Core Curriculum of lower secondary level. This research conducted content analysis of learning indicators in the curriculum by using the NOS analytical framework. The results showed that only 6 out of 15 concepts of NOS were integrated in learning indicators, but covered all 3 aspects of NOS including scientific worldview, scientific inquiry, and scientific enterprise. However, the learning indicators mostly emphasized on the integration of the concepts of NOS in the aspect of scientific worldview and scientific inquiry, but hardly found the integration in the aspect of scientific enterprise. 110 learning indicators out of a total of 147 indicators in the lower secondary school were integrated the concepts of NOS. The most percent of numbers of indicators integrating the concepts were at 9th grade. The results of the analysis showed that NOS is still an important component of the revised science curriculum. However, many NOS concepts were missing from the curriculum. In the curriculum manual, therefore, there should be the suggestions for the connection between science learning indicators and effective methods for teaching NOS.

Keywords: Nature of science, Science learning indicator, Basic education core curriculum

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Introduction

The Nature of Science (NOS) was defined by science educators as a rich description of what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavors [1]. If students deeply understand NOS, they will improve science content learning, understanding about science, being interested in science, and making a decision for scientific related issues. NOS is also an important part of being a scientifically literate person [1-2]. Understanding of NOS helps students relating and evaluating phenomenon to scientific topics and scientific concepts [3]. Students' understanding of NOS also has been assessed by the Programme for International Student Assessment (PISA) under the sub-aspects of epistemic knowledge as indicated in knowledge aspect of the scientific literacy assessment framework for PISA [4-5].

According to the important of NOS, many countries had attempted to promote students' understanding of NOS by integrated NOS concepts into science learning standards and indicators in their science curriculum and the standard for science teachers such as the New Zealand Curriculum [6], the Next Generation Science Standards (NGSS) of USA [7], and the 2020 NSTA Standards for Science Teacher Preparation [8]. In Thailand, the Basic Education Core Curriculum B.E. 2551 (A.D. 2008), NOS had been indicated in the 8th learning strand in the subject area of science called the Nature of Science and Technology. The learning strand explicitly provided details of scientific process, scientific inquiry, scientific attitude, and concepts of NOS which students should learn [9]. In 2017, the learning standards and indicators of science subject area was revised causing reduced number of science learning strand into 3 strands including life science, physical science, and earth and astronomy. The concepts of NOS were intended to integrate into learning standards and indicators of these three new learning strands [10]. There was indicated in the curriculum manual of this revised science learning standards and indicators that teachers should promote NOS to students by referring to 3 aspects of NOS suggested by the American Association for the Advancement of Science (AAAS) including scientific worldview, scientific inquiry, and scientific enterprise [11-12]. However, the NOS concepts stated in the curriculum manual were not explicitly linked to science learning indicators in the curriculum document. Therefore, it was interesting in exploring how the concepts of NOS suggested in science curriculum manual were integrated into science learning indicators under learning standards of 3 science learning strands of science and technology subject area in the basic education core curriculum.

In this study, the concepts of NOS which integrates in learning indicators of science and technology subject area (revised edition B.E. 2560) of the Basic Education Core Curriculum B.E. 2551 of lower secondary level, Grades 7-9, were analyzed by using documentary analysis procedure. The findings from this research would help clarify NOS concepts embedded in science learning indicators which could be used as a guideline for curriculum implementation in designing science learning activities to promote lower primary school students' understanding of NOS according to the revised science learning standards and indicators.

Research Methodology

Purpose of research

The purpose of this study is to analyze the concepts of NOS integrated in the learning indicators of the science and technology subject area (Revised Edition B.E. 2560) in the Basic Education Core Curriculum B.E. 2551 of lower secondary level.

Research Instrument

The analytical framework for analyzing NOS concepts in the basic education core curriculum had been developed through these following steps.

1) Indicating scope of NOS aspects and concepts of NOS under each aspect which should relate to revised science indicators by studying NOS aspects and concepts from the document of Thai science curriculum manual of revised learning standards and indicators for science and technology subject area and Science for All American of AAAS.

2) Developing conceptual framework of NOS which composed of 3 aspects of NOS according to AAAS and concepts of NOS under each aspect.

3) Extracting key words for each concept of NOS in the conceptual framework of NOS found from two curriculum documents including NGSS of USA and Thai Basic Education Core Curriculum B.E. 2551 in science and technology learning area.

4) Developing a draft of analytical framework for analyzing NOS concepts including NOS concepts and key words of all NOS concepts.

5) Evaluating the construct validity of analytical framework by three NOS experts using an index of item-objective congruence (IOC). The IOC of each item was ranged between 0.67 - 1.00, which means that all items can be used. The experts also gave suggestions for improvement the analytical framework.

6) Modifying the analytical framework based on expert feedback.

Research method and data collection

This research is documentary research. The data were collected from a curriculum document provided by the Ministry of Education called Indicators and Core Learning Content of Science Subject Area (Revised Edition B.E. 2560), according to the Basic Education Core Curriculum B.E. 2551. The document was read and looked for words found in the passages of standards and indicators.

Data analysis

This research used document analysis method to analyze data as following steps.

1) Read each learning indicators and found out key words from the passages which related to the key words in analytical framework.

2) Took notes of learning indicator's code which integrated the concepts of NOS in the data collection table.

3) In each NOS concept under each NOS aspect of analytical framework, counted number of learning indicators which integrated this concept.

4) Checked the quality of data analysis by cross-checking between the researchers.

- 5) Analyzed and summarized of the results by using descriptive statistics including number and percentage of learning indicators which integrated NOS concepts in each grade level.

Results and Discussion

From analysis of revised learning indicators of science standards in 3 science strands of lower secondary level, it was found that there were 110 indicators out of total 147 indicators which integrated at least one concept of NOS. When considering by each grade level, there were 32 indicators out of 43 indicators integrating the concept of NOS, which were 74.42 percent of all indicators in Grade 7. There were 39 indicators out of 54 indicators integrating the concept of NOS, which were 72.22 percent of all indicators in Grade 8. There were 39 indicators out of 50 indicators integrating the concept of NOS, which were 78.00 percent of all indicators in Grade 9. Thus, Grade 9 had highest percentage of numbers of the learning indicators that integrated NOS concepts.

The concepts of NOS which were integrated in the learning indicators were covered all 3 aspects of NOS including scientific worldview, scientific inquiry, and scientific enterprise. However, there were only 6 concepts out of 15 concepts of NOS according to the analytical framework were integrated in the learning indicators. The details of concept of NOS and the number of indicators that integrated each concept of NOS in each grade level and in total of lower primary level are shown in Table 1.

Table 1 The concept of NOS and numbers of learning indicators that integrated each concept of NOS

The Concept of NOS		Numbers of indicators that integrate the concept of NOS			total
		Grade 7	Grade 8	Grade 9	
Aspect 1 Scientific Worldview	The world is understandable	16	13	18	47
	Scientific ideas are subject to change	-	-	-	-
	Scientific knowledge is durable	-	-	-	-
	The theory and law have related to each other but differences.	2	3	6	11
	Science cannot provide answers to all questions	-	-	-	-
Aspect 2 Scientific Inquiry	Science demands evidences	9	12	14	35
	Science is a blend of logic and imagination	5	14	11	30
	Science explains and predicts	3	9	7	19
	Scientists try to identify and avoid bias	-	-	-	-
	Science is not authoritarian	-	-	-	-

Table 1 (cont.) The concept of NOS and numbers of learning indicators that integrated each concept of NOS

The Concept of NOS		Numbers of indicators that integrate the concept of NOS			total
		Grade 7	Grade 8	Grade 9	
Aspect 3 Scientific Enterprise	Science is a complex social activity	-	-	-	-
	Science is organized into content disciplines and is conducted in various institutions	-	-	-	-
	There are generally accepted ethical principles in the conduct of science	-	-	-	-
	Scientists participate in public affairs both as specialists and as citizens	-	-	-	-
	Science emphasizes the search for knowledge, whereas technology emphasizes the application of knowledge.	6	4	4	13

From the table, the concepts of NOS under the aspect of scientific inquiry were integrated in the learning indicators with the highest numbers of 84 indicators, followed by the concepts of NOS under the aspect of scientific worldview which integrated in 58 indicators. Lastly, the concepts of NOS under the aspect of scientific enterprise integrated in only 13 indicators. According to the results, it showed that the learning indicators of the revised science leaning standards of lower secondary level emphasized on the integration of NOS concepts under the aspect of scientific worldview and scientific inquiry, but hardly find the integration in the aspect of scientific enterprise. The concepts of NOS under the aspect of scientific enterprise would help to improve students' understanding of the relationship between science, technology and society. This understanding was indicated as one of the aims of science learning in the basic education core curriculum in science and technology subject area which stated that students should concern about the relationship between science, technology, humanity, and environment [10]. Thus, if the learning indicators did not emphasize on this NOS aspect, students might loss opportunity to develop their understanding to accomplish this aim of science learning.

Although it was found that the indicators integrated with the concept of NOS covered all 3 aspects of the AAAS [12], only some NOS concepts in each aspect were considered integrated. For the aspect of scientific inquiry, there were 3 concepts of NOS integrated in the learning indicators including science demands evidences, science is a blend of logic and imagination, and science explains and predicts. For the aspect of scientific worldview, there were 2 concepts of NOS including the world is

understandable and the theory and law have related to each other but differences integrated in the learning indicators. Lastly, there was only 1 concept of NOS under the aspect of scientific enterprise which was science emphasizes the search for knowledge, whereas technology emphasizes the application of knowledge integrated in the learning indicators. Thus, there were many NOS concepts which were not integrated into indicators such as scientific ideas are subject to change, scientists try to identify and avoid bias, and science is a complex social activity. This finding was in accordance with the conclusions from the research results of McComas and Nouri [13] who analyzed NOS in NGSS of USA. They found that NOS appeared less than it should be and many important concepts of NOS were missing from the NGSS. For example, the NOS concepts, such as scientific investigation use a variety of methods and science is a way of knowing were recommended in NOS category of NGSS in the Appendix H but they were not included in the standards section of NGSS document for middle school level.

According to research finding of McComas and Nouri [13], the NOS concepts from Appendix H of NGSS were related to the practice of science and crosscutting concepts such as energy and matter; scale, proportion, and quantity; and stability and change, but were not related to science content of the standard. Unlike their findings, in this research, it was found that the NOS concepts were embedded in learning indicators which related directly to scientific content in Thai science learning standards. For lower secondary school level, the NOS concepts were integrated in the learning indicators under all 3 learning strands including biological science, physical science, and earth science and astronomy. The NOS concepts were also found in every learning standard under each learning strand, although they were not integrated in every sub-topic. The number of learning indicators and sub-topics which integrated NOS concepts across Grades 7-9 are shown in Table 2.

Table 2 The number of learning indicators and sub-topics which integrated NOS concepts across Grades 7-9

Learning Strand and Main Topics of Learning Standards	Number of Learning Indicators across Grades 7-9		Sub-topics with NOS Concepts Integration
	In Total	Integrated NOS	
Strand 1 Biological Science			
Standard 1.1 Ecology and Natural Resources	6	5	Interaction of living and non-living things, Types of relationships between organisms, Food web
Standard 1.2 Structures and Functions of Living things	35	18	Cell, Photosynthesis, Plant structure, Systems of human body, Plant tissue culture and plant propagation

Table 2 (cont.) The number of learning indicators and sub-topics which integrated NOS concepts across Grades 7-9

Learning Strand and Main Topics of Learning Standards	Number of Learning Indicators across Grades 7-9		Sub-topics with NOS Concepts Integration
	In Total	Integrated NOS	
Standard 1.3 Genetic, Biodiversity, and Evolution	11	8	Chromosome gene and DNA, Genetic inheritance, Cell division, Genetic disorder, GMOs, Biodiversity
Strand 2 Physical Science			
Standard 2.1 Matter and Chemical Reaction	24	18	Classification of elements, Classification of substance, Atomic structure, Model of matter particles, Purification, Solubility and solution concentration, Polymers, ceramics, and composites, Chemical reaction
Standard 2.2 Force and Motion	16	16	Atmospheric pressure, Net force, Force and fluid pressure, Buoyant force, Frictional force, Moment of force, Field force, Speed, velocity, and displacement
Standard 2.3 Energy and Wave	34	28	Thermodynamics and the change of state of matter, Heat and substance expansion or contraction, Heat transfer, Work and power, mechanical energy, Law of conservation of energy, Electric, Formation and composition of waves, Electromagnetic wave, Light reflection and refraction, Lighting and visual equipment, Visibility and brightness
Strand 3 Earth Science and Astronomy			
Standard 3.1 Universe, Galaxy, Solar System and Space Technology	4	4	Orbit of the planets, Season, Phase of the moon, Space technology
Standard 3.2 Geology, Weather and Climate	17	13	Elements of weather, Weather prediction, Climate change, Fossil fuels, Earth structure, Weathering, erosion, and sediment deposition, Characteristics and development of Soil, Surface water and groundwater, Geohazard

According to the data, all indicators in the Standard 2.2 Force and Motion and Standard 3.1 Universe, Galaxy, Solar System, and Space Technology integrated the NOS concepts. For other standards, the NOS concepts were integrated in more than half of the number of indicators under each learning standards with various sub-topics. This finding indicated that the revised science learning standard still concerned about NOS concepts which related to the learning process of science although NOS concepts were limited to only 6 concepts. If science teachers could indicate the NOS concepts which were integrated in these learning indicators, they might see many opportunities for teaching these 6 concepts in various science topics to lower secondary school students.

The analytical framework with key words was developed and used for analyzing NOS concepts from these learning indicators in this research. This was because of the new revised science learning standards was designed with the intention to embed NOS concepts within learning indicators. No learning indicator had the statements of NOS concepts for students to learn and develop their understanding of NOS explicitly. The example of learning indicators which found integrated 6 NOS concepts under 3 aspects are shown in Table 3. The bold letters indicate keywords that relate to the NOS concepts.

Table 3 Example of learning indicators which integrated 6 NOS concepts under 3 aspects

The Concept of NOS	Keywords of the Analytical Framework	Science Learning Indicators
Aspect 1 Scientific Worldview		
The world is understandable	Explain concept/ phenomenon	SC 1.1 Grade9/1 Explain relationship between the components of ecosystem from exploration
The theory and law have related to each other but differences.	Discuss results from observation/experimentation with existing theory	SC 3.1 Grade9/1 Explain the orbit of planets around the sun by gravitation from the equation $F = (Gm_1m_2)/r^2$
Aspect 2 Scientific Inquiry		
Science demands evidences	Make scientific explanation from empirical evidences	SC 1.2 Grade7/5 Explain process of diffusion and osmosis from empirical evidences and give example of diffusion and osmosis in daily life
Science is a blend of logic and imagination	Create model to explain or communicate scientific concept	SC 3.2 Grade8/4 Create model to explain earth structure according to chemical components from data gathering

Table 3 (cont.) Example of learning indicators which integrated 6 NOS concepts under 3 aspects

The Concept of NOS	Keywords of the Analytical Framework	Science Learning Indicators
Science explains and predicts	Use scientific explanation to explain or predict	SC 2.2 Grade8/1 Predict motion of object effected by resultant force when many forces which acting on the same subject are collinear
Aspect 3 Scientific Enterprise		
Science emphasizes the search for knowledge, whereas technology emphasizes the application of knowledge.	Use scientific knowledge for advancing technology	SC 2.3 Grade7/7 Design, select, and develop equipment for solving problems in daily life by using knowledge of heat transfer

According to the document analysis procedure, it was found that although the researchers had analytical framework with keywords for analyzing NOS concepts integrated into learning indicators, some indicators did not state the keywords that exactly matched the analytical framework. The researchers had to interpret from the whole passage whether this indicator integrated with the NOS concept. However, this interpretation was subjective and need the discussion and cross-checking between the researchers. For example, from the Table 3, the concept of the theory and law have related to each other but differences, there was no statement of Newton's Law of Gravitation explicitly written in the indicator, only formulation was found. The researchers had to consider whether this formulation represented the scientific law and related to this NOS concept. In the concept of science emphasizes the search for knowledge, whereas technology emphasizes the application of knowledge, the indicator did not directly use the word, 'technology'. It rather stated the technological process including design, select, and develop equipment for solving problems which could refer to the developmental process of new technology. Thus, the researchers also needed to interpret and link to the NOS concept. This raised the concerned that it would be harder for teachers who were not familiar with the NOS concepts to be able to indicated NOS concepts integrated in learning indicators for developing NOS learning objectives and activities according to this revised science standards and strands. Thus, the suggestions for the connection between science learning indicators and NOS concepts might be added to the recent Thai science curriculum manual of the revised science learning standards and indicators similar to the suggestions for the connection found in NGSS document [7]. The example of how NGSS indicated the linkage between learning standards and the NOS concepts is shown in Figure 1.

MS-LS1-6 From Molecules to Organisms: Structures and Processes

Students who demonstrate understanding can:

MS-LS1-6. Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. [Clarification Statement: Emphasis is on tracing movement of matter and flow of energy.] [Assessment Boundary: Assessment does not include the biochemical mechanisms of photosynthesis.]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories. <ul style="list-style-type: none"> Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. 	LS1.C: Organization for Matter and Energy Flow in Organisms <ul style="list-style-type: none"> Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. PS3.D: Energy in Chemical Processes and Everyday Life <ul style="list-style-type: none"> The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. (secondary) 	Energy and Matter <ul style="list-style-type: none"> Within a natural system, the transfer of energy drives the motion and/or cycling of matter.
Connections to Nature of Science Scientific Knowledge is Based on Empirical Evidence <ul style="list-style-type: none"> Science knowledge is based upon logical connections between evidence and explanations. 		

Figure 1 An example of how NOS concept was indicated in the standards section of NGSS document.

From the excerpt of NGSS document, there was the section, ‘Connections to Nature of Science’ at the bottom of the column, ‘Science and Engineering Practices’ under the performance expectation of the learning standard, MS-LS1-6 ‘From Molecules to Organisms: Structures and Processes’. This section stated the NOS concept related to the science and engineering practice that related to the learning standard. Thus, for Thai revised science learning standards, the concepts of NOS related to science learning standard could also be stated under each relevant learning indicator in the science curriculum manual.

Moreover, in order to help science teachers implementing the NOS instruction according to the revised science learning standards, the science curriculum manual might give a guideline for NOS instruction for each NOS concepts to cover all 15 concepts as indicated in Table 1. The examples of the NOS learning activities according to each learning indicators which integrated NOS concepts should also be shown in the manual. These might help assure that science teachers would still develop students’ understanding of NOS. Thus, the aim of this revised science learning standards which stressed that students should understand the boundary and limitation of NOS and aware of interrelation between science, technology, human, and environment would be accomplished [10].

Conclusions

Although the science learning standards and indicators of the science and technology subject area (Revised Edition B.E. 2560) of lower secondary level in The Basic Education Core Curriculum B.E. 2551 in the content strand of life science, physical science, and earth and astronomy did not explicitly state NOS concepts, according to the analysis of the concept of NOS integrated in the learning indicators, 110 indicators out of 147 indicators integrated at least one concept of NOS. Among 3 grade levels, Grade 9 had highest percentage of numbers of learning indicators which integrated NOS concepts with 78.00 percent. The results of the analysis showed that the concepts of NOS in all 3 NOS aspects were integrated in the learning indicators. However, the learning indicators mostly emphasized on the integration of the concepts of NOS in the aspect of scientific worldview and scientific inquiry, but hardly

found the integration in the aspect of scientific enterprise. It was also found only 6 NOS concepts out of 15 concepts integrated in the learning indicators. The missing NOS concepts should be more emphasized in the curriculum and there should be the suggestions for the connection between science learning indicators and NOS concepts in curriculum manual for helping teachers' implementation of the curriculum more effectively to enhance students' NOS understanding. Therefore, in the curriculum manual, there should be the suggestions for the connection between science learning indicators and NOS concepts, and effective methods for teaching NOS especially for missing concepts of NOS.

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