# Do we have a place for nature of science (NOS) in Biology teaching?

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## Abstract

The nature of science (NOS) is important in science teaching. Many countries embedded NOS in core curriculum documents as an essential component in science teachings such as developing conception, skill, and attitude in science in the learner. This case study was conducted at a university located in Lower Northern Thailand to explore teaching nature of science in Introductory Biology course in both lectures and laboratory sessions that were taught. Participants are three instructors (N=3) from the Department of Biology, Faculty of Science. Data were collected using qualitative instruments, including a questionnaire, semi-structured interview, classroom observation, lesson plans, and teaching materials. The results indicated that most of the instructors are strong in contents. The students put all of their focus on the teacher, and those students mostly listen, although, in activities session, students work alone. Even though some classes were questions and answers between teachers and students or discussion in the class, the instructors did not adopt the NOS in their lesson plans. Also, they used confirmatory and guided inquiry in their laboratory sessions. However, we can conclude that they used a weak and implicit approach to teach the NOS. An effective professional development program and strategies on teaching NOS at the college science level are discussed in this report.

***Keywords*****:** *Nature of science, Biology teaching, case study, Classroom exploration, College Biology Teaching*

## 1. Introduction

Everyone needs to understand science and use for their daily lives. Science can be used to solve problems choosing right information for making decisions (AAAS, 1993). In order to science student who pursue careers in science in the future, they have a vital role in the society. They will be the experts in the field, so they must have the ability to solve the problems relating to science and technology in the same way scientists answer a question or explain a phenomenon. They need to be a science literacy person.

The nature of science (NOS) is a study which related to history and philosophy of science (McComas, 2000). It explains the uniqueness of science in various aspects including observations and inferences, change of scientific theories, scientific laws vs. theories, social and cultural influence on science, imagination and creativity in scientific investigations, and Methodology of scientific investigation. NOS explains what science is and the work of science, and the interrelationship between society and society (McComas, 2000). NOS includes the definition of science, the concept assumption and values that are created (Lederman and Zeidler, 1987 ; Ryan and Aikenhead, 1992 ; Abd-El-khalick, 2001). The construct of NOS has been proposed by a number of scholars. One of the most well known is Lederman's framework (Lederman, 2007); Lederman and Zeidler, 1987) which consist of 1. subject to change, the accepted views of science knowledge can change over time 2. empirically based, scientific knowledge are based on or derived from observations of the natural world 3. science is subjective issue, science knowledge is a human endeavor which can also be affected by social, political or religious convictions 4. necessarily involves human inference, science knowledge can also be affected by inference from individual scientist with a personal background, biases, and or theory -laden and 5. science need imagination and creativity (involves the invention of explanations) and scientists have to use their imagination to come up with explanations 6. socially and culturally embedded, the social and cultural elements such as politics, economics, power structures, religion and philosophy will affect the science knowledge and two additional important aspects

are the distinction between observations and inferences, and the functions of and relationships between science theories and laws (Lederman, 2007).

Many studies and reports conclude that the NOS is necessary components at any student level to help students develop their own conception, skill, and attitude in science. NOS is an essential component in achieving scientific literacy and has been focused in many national documents : American Association for the Advancement of Science (AAAS), Science in the New Zealand, Canada Ontario Curriculum (AAAS, 1989 ; Abd-El-Khalick, 1998) and Thailand Science Curriculum Standards has set a target of science teaching that requires the integration of NOS. In Thailand, there are many studies focusing on understanding the nature of science and most were conducted with primary and secondary students, pre-service and in-service teachers (Suttakun,Yutakom and Vajarasathira, 2010) but few with college science students and the faculty members of science. However, there are no studies that have examined NOS teaching in the faculty of science. It was quite challenging and interesting to study teaching NOS at a college level. This research was interested to study and aimed to develop an understanding of the NOS in the faculty of science in the future.

## 2. Objectives

This study was to explore teaching NOS in Introductory Biology course in lecture and laboratory sessions. The research question guiding this investigation is whether and how did lecturers address NOS in his or her teaching?

## 3. Materials and Methods

This study surveyed Thai Biology lecturers in their teaching of NOS Case study research design was employed to enable an in-depth investigation to take place and provide detailed descriptions of the study's findings using a variety of qualitative methods including questionnaires, surveys, interviews, audio and video-taped class sessions, classroom observation, a collection of the lesson plan and teaching materials.

### 3.1 The Participants

In the first semester, the participants were three lecturers, all holding a master's degree; 2 in the field of Biotechnology and the other in Biology. Pseudonyms were assigned to each participant, student, and institute for an ethical reason and have been used throughout this paper. They were Jinn, a 29 years old female lecturer who holds a Master of Science in Biology, Ben and Singh, 32 and 33 years old male lecturers who earned a Master of Science in Biotechnology. The lecturers were asked by the first author to complete questionnaires. Besides, they were interviewed and observed their teaching. Participants information was summarized in Table 1.

**Table 1** Participant information

| Name (pseudonym) | Age | Gender | Teaching experience (in Biology) | Education |
|---|---|---|---|---|
| Jinn | 29 | female | 4(2) | M.Sc Biology |
| Ben | 32 | male | 4(2) | M.Sc Biotechnology |
| Singh | 33 | male | 5(3) | M.Sc Biotechnology |

### 3.2 Data collection

Data were collected through the following methods during Introductory Biology's course by the questionnaire of science teaching (QST). A questionnaire comprising 22 items were used to assess participants' teaching of NOS. The questionnaire was employed in order to assess participants teaching on the targeted features of Introductory Biology 's lectures and laboratories at the beginning of the course. The questionnaires consist of several questions that ask participants to rate in statements that most match the behavior of the teaching of lecturers.

3.3 Interviews and classroom observation

During the course, the first author visited and observed each participant and conducted a semi-structured interview with the participants inside their classrooms to provide ideas about science, NOS, and their teaching styles via open-end questions. The interviews were asked to provide evidence to support their claims in various aspects including : the most important things to emphasize in teaching, teaching style and activities in classroom, goal of teaching, evaluation and NOS in their instruction. The interviews were audiotaped and transcribed verbatim. The video recording was employed during the course. The first author ask for a collection of lesson plan and teaching materials in the Introductory Biology's course from participant.

3.4 Data Analysis

The data from questionnaire were analyzed. The participants' responses to the questionnaire were compared to the expression of NOS teaching in their classroom, interviews, lesson plan and teaching materials. Content analysis was applied.

## 4. Results and Discussion

4.1 Exploring the NOS teaching

Findings from different data sources, including interviews and observations, found that the lecturers had very lecture-based instruction. They felt that content was the most important and they had the responsibility to present the content to the students. All lessons observed showed evidence of a lecture-based approach. Findings from the interviews also confirmed that the teachers felt that content knowledge was vital for their instruction, as shown below.

> "The goal of teaching this course as I expected is that students must learn the basic content because they use this in their next courses or the future study. They should have a good foundation. I think content is most important.", Jinn said

> Jinn mentioned in their questionnaires that she does not have strategies for teaching the NOS. She said that she had not specifically been taught the characteristics of NOS. She focused on content in biology.

> Meanwhile, another lecturer noted,

> "Did you teach or integrate anything in this course aside from the content related to science?"

> "No, I can't remember in this time, maybe I wouldn't teach," Jinn said.

> Singh also mentioned in questionnaires that he does not have strategies for teaching the NOS. He feels the content in biology is the most important in a biology course, as this situation:

> Researcher: What is the most important thing or a goal in Biology course.

> Participant: "I need them to understand in 'Biology'. That what I taught them, at least they know in the organism, living thing, our body. Biology is really closed to us more than we think, we need to



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understand the natural world, living systems. They should know about the content of each organism type. I wanted to give them all chapters in textbooks."

Participant's teaching

We also observed the teaching atmosphere in the classroom. The results indicated that the lecturers tended to focus on the science content through the questions to construct students' ideas about the content in each chapter. For instance, Jinn stated in response to the interview on 13 June 2013, 4.25 pm, as shown below.

"My teaching style is lecture type, both in the lecture and laboratory. I usually focus on content teaching. Sometimes, I give them exercises, some reports or homework," Jinn said

From classroom observation, Jinn is a lecture-type lecturer. Sometimes she raises a question before teaching each content, followed by an explanation to students. Students were asked at the beginning of each topic.

For example, as in the following event;

"What is the meaning of *'substrate'?* "" Jinn asked.

"Precursor," student in the front row said.

"In the beginning, precursor bind with phosphate, and enzyme pyruvate kinase come to accelerate the phosphate groups and dropped it out. So phosphate just binds to ADP and integrated with two phosphate groups. After that, the third molecule becomes an ATP ....."

Jinn asked and replied by herself instantly. She went on non-stop explaining until the finish of the substrate topics (about five minutes). Classroom observation also revealed that Jinn did not address NOS in her instruction.

The question of Jinn was simple and did not engage or made students curious. For example,

"What is it?" Jinn pointed her finger to the picture of three-dimensional protein on the screen.

"Enzymes," responded by a student.

"Think about the last homework, remember?" Jinn asked.

"What function of the enzyme?" Jinn asked again.

"Food digestion," one of student answered.

"Do you know about other enzymes?" Jinn asked.

"Amylase" "lipase" student answered.

"What functions the lipase?" Jinn asked.

"Fat digestion," student response.

Singh also taught in the same way as Jinn. He stated in response to the question of the interview on 27 July 2013 at17.49 pm, as shown below.

"My teaching style? I went to talk to the kids before I taught. After that, I don't waste of my time, so I begin. I prepare the content for the student. How to prepare?. I pick up some content that I think they should know, yeah…. I always asked the question before I taught, I need to know prior knowledge, I gave them some question."

Singh did not teach by engagement. He strictly gave questions. He wanted the students to answer his question, then he explained to the students via his slide show.

For example, as in the following event;

In chapter 4, he taught the 'reproduction and growth of organisms'.

The participant walked to the front, holding papers in his hand, and then asked students.

"What is reproduction?" Nobody answered. Singh asked again.

"Guys, try to define the reproductive mean?" Students began to talk and tried to answer, but no one volunteered for the question. Singh further asked,

"How about your understanding about reproduction, just let me know." When he saw that no one answer, he walked to get the student list and called up one student.

"Mantra (pseudonym)"

"You give a brief description of reproduction," Singh asked again.

Students kept silence for a moment before answered that question.

"Creat a new life," Mantra said.

Singh repeated what the student has said, and he asked that:

"Creating a new life, yes, but not precisely," then he went to change the next slide show and said,

"Ah, let's see what reproduction means. It is the process of reproduction of the living things....." he explained until the end of the lecture in reproduction topics.

Singh taught by using a lecture. In each slide, he digested the essence of content to explain to the students. No NOS was included here. Sometimes, he had some questions to create concepts in biology:

Example:

When Singh was teaching in the chapter of 'cell division'.

"That is Planarian. You see that?". He pointed to the Planarian image.

"If we cut it off by knife and divided into four pieces, each can be regeneration into a new one, just like a starfish. A starfish can create new cells to fix themselves, blend with the original pieces. If it is missing half of it, they will create a new one to complete itself.", and Singh asked that:

"So, a lizard can regenerate its organ?".

"No" "It's just for escaping from a predator." Students replied.

"Yes," Singh said.

"Some species can reproduce by larvae without mating. The growth of the embryo can develop to new creatures direct, found in the bee."

Ben was just different from other lecturers as he taught by engaging with a common language but still lacking in gaining reflection from the student. He stated in response to the question of the interview on 27 July 2013,16.47 pm, as shown below.

"My teaching style? Students must understand its content. We must teach in simple vocabulary. Because most of the words in the Biology course are specific vocabulary." Ben said.

Ben was teaching by engagement. He worried in a big load of content. He didn't teach in content too much as he didn't want students to get boring in learning, as he said below.

"It would have to add for the children, what they called it?. ac…activity?... active learning yes! Active learning. We must provide children with fun learning because the kids always get bored. I have summary the content in my PowerPoint before I taught. I taught only in the important and necessary topic. If we add them all the content, it does not succeed, and they will not remember anything. They will get bore in learning."

Ben taught in a lot of informal languages. He always spoke in a common language. While teaching about reproduction, Ben usually asked a question, but he did not expect the student to respond because he explained or answered the question by himself immediately. For example,

Ben: "What is reproduction? Do you know about sexual reproduction is?. What is reproduction?"

"I can tell you this course is about 'Origin of life'. 'Origin of life', it's about what?"

Ben asked again.

"All creatures born to conserved their species, isn't it?" Ben said.

Students still kept silent, so Ben talked about reproductive.

"There are asexual reproduction and asexual. Can you give me some examples of asexual?", Ben said.

"Protozoa," one student answered.

"Ah.. protozoa, that's it! Protozoa are called as lower animals, anything else?" Ben asked, but he did not wait for response, and he said, "Incomplete reproductive system. It is asexual reproduction."

Another example:

"Mycovirus, you see that?". Ben pointed to the screen.

"Its cap will go up on the bacterial chromosome and then try to integrate on it then sent the viral DNA through the cell membranes in order to replication until finishing."

Ben tried to engage the students. While Ben taught about the reproduction of plants, he attempted to bring up the strawberry story to link with biology content. For example,

"Asexual reproduction in plants uses 'sterol'. Do you know about sterol? Sterol is a kind of plant organ we also found in broccoli. Strawberry!, also in strawberry. Have you ever seen some strawberries tree? Are you ever been to Petchaboon? (The province that plants strawberry) , right? It is quite close to our province. Can you imagine of strawberries tree? It had a climber to linked with another plant, that's call sterol."

From the evidence, Jinn is a lecture-type lecturer. She often raised a question before teaching each content, followed by an explanation of the content for students, but she did not engage them to learn. However, Singh focused on content and instructional media. He did not have strategies for teaching the NOS and felt that the content in biology is very important. Singh always taught by using a lecture and preferred to digest the main idea of content to explain to the students. He also had some questions to create concepts in biology. As for Ben, he taught by engagement. He avoided giving a big load of content in the classroom. Ben also taught in a lot of informal languages. He always spoke in a common language to make the students clearly understand the conception.

In summary, all participants taught by giving lectures e and teaching Biology content, then try to confirm what they have lectured by conducting the experimentation in the laboratory room as a confirmatory and guided inquiry. From the classroom observation, participants rarely addressed NOS in their instructions. Sometimes, they talked about news related to Biology and had free-talk before or during the session inside the classroom. However, they did not link this with NOS. They mostly lectured by sitting on the chair in front of the room and start a slide show presentation. Teaching in content is more than 80% of their Introductory Biology lectures. In laboratory teaching, they briefed the direction again on the blackboard after teaching in the lecture class. The students would see the steps in the laboratory from the texts. By examining the lesson plan and teaching materials, it was found that the lesson plan did not show a strategy for teaching the NOS in their courses. Also, we noticed that they used the same presentation files in their teaching. In the course syllabus, they intended to teach specific content and just evaluate only. The objective is only to understand the content of each chapter, and we did not find the intention of teaching NOS in their teaching document. In achieved research of NOS teaching, they used interactive historical vignette (IHV). The NOS instruction integrated within content through interactive historical vignettes was effective in enhancing the understanding and avoiding de-contextualization, and their method can be effective in improving the students' understanding of the nature of science. (Clarly & Wandersee, 2006). Many research works recommend that biology teaching should be undertaken by explicit NOS teaching, and the results of many studies indicate that the explicit-reflective approach can be effective in promoting the NOS understanding. (Celik and Bayrakceken, 2012).

Participant students' views of NOS

Participant teaching information was summarized in Table 2.

**Table 2** Participants teaching

| Name (pseudonym) | NOS teaching | Teaching approach | Teaching style | Biology teaching's belief |
|---|---|---|---|---|
| Jinn | No | Lecture-based | - Focus on content teaching.<br>- Raise a question before teaching content, followed by explanations. | The student must archive the basics content because they will be used in the next courses or further study. |
| Ben | No | Lecture-based | - Use simple vocabulary.<br>- Avoid a specific vocabulary and use informal talk.<br>- Engage in the classroom. | The teacher must provide fun learning because the kids always get bored. Teach only the important and necessary topic. |
| Singh | No | Lecture-based | - Talk to the kids before teaching them.<br>- Choose some really important content.<br>- He always asks the question before teaching and needs to know students' prior knowledge. | Understanding of Biology depends on instructional media. |

4.2 NOS teaching Discussion

The data gathered in this study, collected from questionnaires, interviews, and video recording, revealed that participants did not integrate NOS in their teaching. The classroom observation indicated that most of the instructors were usually content-driven and teacher-centered although they sometimes asked the students questions and allowed open discussion before and during the session. The present results indicate that lecturers did not address the NOS in their teaching or instruction. They were unable to apply the characteristics of NOS integrated into instruction. They might have an inadequate understanding of the NOS and did not know how to integrate it into their course. Findings suggested that they believed in teaching content, and they focused on content in each chapter. In the laboratory session, they used a cook-book manual to confirm what they had lectured. However, many research works have shown that science teaching by inquiry-based approaches is more effective than passive learning (Cunningham et al., 2010; Derting and Ebert-May, 2010). An inquiry-based approach is an important aspect of NOS. An inquiry-based laboratory asks students to address a challenge, solve a problem, test a hypothesis, explain a phenomenon, or answer a question in the same manner that a real scientist approaches to deal with a research question (The Wisconsin Program for Scientific Teaching, 2005). Many evidences are suggesting that teaching with an inquiry-based laboratory encourages learners to understand better than a lecture-based approach. An inquiry-based, learner-centered learning experience in the biology curriculum was associated with long-term improvements in learning (Derting and Ebert-May, 2010). Researchers suggested that Biology teaching should allow students to be more reflective in their understanding. Many reports have suggested that reflective instruction is very effective (Akerson, Abd-El-Khalick, and Lederman. 2000). Researchers suggest the most common form of science teaching, inquiry-based approach, for the NOS which incorporated with reflection. This method can represent authentic scientific endeavors and expand to project-based science (PBS). In this approach, the student can learn by organizing around the projects. They can decide to construct a way to solve the problems when learning at the college science level.

## 5. Conclusion

From this study, participants are strongly instructor-centered, which does not provide students with active learning experiences or get in situations in which students take the role of scientists. Integrating NOS in teaching will allow science lecturers to better instruct about teaching science through inquiry as it has been strongly recommended by prior research (Morrison, 2013). This study provides a strong argument that those lecturers doing and teaching science might not understand NOS. They should add an effective teaching style, focus on activities and emphasize student-centered learning through various learning tasks that integrated NOS. Active learning, student collaboration and problem solving should be concerned. There must be a professional development to equip them with understanding of nature of science and how to address it in their instruction.

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