The Development of Students’ Nature of Science Views in Cellular Respiration Context

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Abstract. The study aimed to investigate the development of students’ views of nature of science (NOS) in cellular respiration context, including scientific knowledge is tentative, scientists are creative, scientific knowledge is based on empirical evidence, science is a complex social activity, and science has global implications. Grade X students (n=15) registered in English Program (EP) of a high school in Phitsanulok Thailand were taught about the NOS in cellular respiration context through the implementation of conceptual change approach. The intervention had been conducted in three repetitive cycles of action research, along with the utilization of a series of instruments: the Nature of Science Questionnaire (NOSQ) and Cellular Respiration Questionnaire (CRQ), nine 55-minute lessons, semi-structured observations, and semi-structured interviews. The result of content analysis and triangulation showed that the implementation of conceptual change approach in this study had been effective in enhancing students views of targeted NOS aspects, in which the highest improvement regarding scientific knowledge is tentative and scientist are creative. Integration of Nature of Science aspects in cellular respiration context can be used to enhance students understanding on tentativeness nature of science and the role of creativity in the development of scientific knowledge.

1. Introduction
Science education reform in many countries not only focus on developing students’ scientific conceptions, but also focus on improving students’ understanding of the nature of scientific knowledge (NOS) [1,2,3]. The reform is an answer to the urge of creating societies with the capability to survive in a science-based global community where the survival of societies depends on how wisely they use scientific understanding on personal and political decision making [4]. In line with the urgency, educational reform document in Thailand has also acknowledge the importance of understanding NOS. In the document, science competencies are distinguished into 8 strands which consists of requirements for students to understand knowledge of science (i.e. Strand 1 to 7) as well as knowledge about science which is also known as the Nature of Science (i.e. Strand 8). Although it is separated into different strands, the teaching of indicators in strand 1 to 7 are required to be coupled with indicators in strand 8. In other words, teaching the knowledge of science are required to be integrated with the knowledge about science [3].
Researchers on the realm of science education has considered the understanding of NOS as necessary to enable students to understand the norms of scientific community that embody moral commitments that are of general value to society, to cultivate positive attitudes toward science, and to facilitate the learning of science subject matter [5,6,7]. Despite the potential advantages of understanding NOS, many research documents showed that students in many countries, including Thailand, still hold inadequate understanding regarding the nature of scientific knowledge [2,8].

One of the factors that may cause students’ inadequate understanding of NOS is classroom instruction that failed to considered students’ preconceptions [9]. Students whose preconceptions conflict with new information might disregard or discount the new information in favour of their existing belief [10]. Another factor is teachers’ reluctance to incorporate NOS aspects in their instruction. In Thailand, science teachers teach NOS implicitly [11], in which they had not planned to teach NOS, to make students aware of the NOS, and to elicit students’ ideas on NOS throughout the instruction. It might relate to the position of NOS which are not being tested in the final examination, despite being explicitly required to be mastered in the basic education curriculum. Thus, the teaching of science concepts without addressing NOS aspects were not perceived as disadvantageous by the teachers. Moreover, incorporating NOS aspects into the instruction means that teacher will need to put more time and effort for their teaching. Accordingly, many teachers decided not to teach NOS aspects in favour of their teaching of scientific concepts.

Conceptual change approach has been suggested as a potential teaching approach to enhance students’ nature of science views. The approach has been found superior in enhancing students NOS views compared to explicit reflective approach [12,13]. Researchers who had implemented conceptual change approach in their study suggested that the effectiveness of this approach in improving students’ conceptions lies upon the set of guidelines which had successfully help students to gain experience in grasping the concepts, i.e. identifying common misconception, providing scientifically correct explanations, and giving them opportunity to practice the correct conceptions [14]. The potential of conceptual change approach in helping students to comprehend the concepts being taught was the reason behind the implementation of the approach as an attempt to give equal attention to both NOS and scientific concepts, i.e. cellular respiration.

Incorporating NOS aspects into the teaching of cellular respiration is a way of facilitating comprehensive understanding of students on cellular respiration concepts, since they will learn not only the concepts, but also the way of how such concepts have been developed by scientists. Despite aiming to enhance both NOS and cellular respiration conceptions, this study would focus on explaining the development of students’ nature of science views when the targeted NOS aspects were taught through the implementation of conceptual change approach in cellular respiration context. The research question being investigated is “What are the influence of the implementation of conceptual change approach on the development of students’ nature of science views in cellular respiration context?”

2. Method
2.1. Participants
Research participants were Grade X science students (n=15) registered in English Program (EP) of a high school in Phitsanulok, Thailand. The participants were native Thai speakers. However, the teaching and learning activities in EP program are delivered in English. All of the participants have been registered in EP since Grade VII, which means that they already have experience in learning by using English for at least 3 years. Also, the students had passed general test before entering EP. The test provided by the school to ensure that all students joined in EP has the basic skills required to succeed in the program.

2.1.1. Instruments. Participants’ views of NOS aspects were assessed by using Nature of Science Questionnaire (NOSQ) which was developed by the researcher to assess 5 aspects of NOS addressed
in this study. The questionnaire consists of 15 questions which was prepared to assess students’ NOS views on cellular respiration context. The content validity of the questions had been provided with the views of two experts. A semi-structured interview guide was also provided to gain more information about students’ views on targeted NOS aspects as well as to validate their response on the questionnaire.

2.1.2. Data Collection. The data collection was conducted in the second semester of 2016 academic year. A pre-test was administered prior to the teaching intervention to assess students’ preconceptions regarding targeted NOS aspects. The intervention was conducted in a nine 55-minutes lesson. Following the intervention is a post-test to assess students’ conceptions on targeted NOS aspects after being taught through the conceptual change approach during the intervention. Both in pre- and post intervention, The NOSQ was administered, followed by a semi-structured interview of 20% participants to gain more information on their NOS views.

The teaching intervention was conducted in 9 teaching periods, in which each period lasted for 55 minutes. There are 5 aspects of NOS being addressed under the cellular respiration concepts, including scientific knowledge is tentative, scientist are creative, scientific knowledge are based on empirical evidence, science is a complex social activity, and science has global implications. The concepts were addressed under the three main topics of cellular respiration, namely energy, respiration and breathing; aerobic respiration; and anaerobic respiration. Each topic was taught through 5 main steps of teaching, namely eliciting preconceptions, presenting common misconceptions, presenting targeted concepts, raising the status of targeted concepts, and reflecting on concepts learned.

2.1.3 Data Analysis. Students’ response on NOSQ were analyzed through content analysis which involved careful reading and judgement on each response. Students’ response on the questionnaire were retyped verbatim. Researcher read the response thoroughly and pick the main point from each response which will then be used as the basis for categorization. The categorization was conducted exhaustively to cover all the patterns of students’ responses. After categorizing, the data were reread and were reviewed to find out the emerging patterns of students’ responses. Three main categories in this study are as follows:

a. Informed, refers to more desirable NOS views which are aligned with the NOS aspects as explained in science standard documents.

b. Transitional, refers to responses which consists of parts that are aligned with the NOS aspects explained in the science standard documents and parts that are not aligned with the documents. In this category, the statements are neither naïve nor informed as it is a combination of different, and at times contradictory, views of NOS aspects.

c. Naive, refers to responses which are not aligned with the NOS aspects explained in science standard documents.

3. Result

Table 1. Categorization of Students’ NOS Response on 5 Aspects of the NOSQ Pre and Post Intervention

| NOSQ     | Empirical Evidence | Creativity in science | Tentativeness | Social aspects | Global Implication |
|----------|--------------------|------------------------|---------------|----------------|--------------------|
|          | Pre (%) | Post (%) | Pre (%) | Post (%) | Pre (%) | Post (%) | Pre (%) | Post (%) | Pre (%) | Post (%) |
| Informed | 0       | 13       | 0       | 40       | 0       | 13       | 0       | 13       | 0       | 13       |
| Transitional | 33     | 73       | 33      | 53       | 7       | 87       | 13      | 73       | 7       | 73       |
| Naive    | 67      | 13       | 67      | 7        | 93      | 0        | 87      | 13       | 93      | 13       |
### Table 2. Example of Students' Responses on Targeted NOS Aspects

| NOSQ Pre-Intervention                                                                 | NOSQ Post-Intervention                                                                 |
|---------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| **Empirical evidence**                                                                |                                                                                       |
| “There is no difference between science knowledge and arts, because knowledge is from everything.” (S2) | “The things that make both two things different is that knowledge of science we will do an experiment many times to try to prove it, but knowledge of arts will come out from your heart and it is not going to be the same all the time” (S2) |
| **Creativity in Science**                                                             |                                                                                       |
| “Science must use evidence and knowledge can’t use feel or creativity.” (S6)          | “Yes, it is important because creativity can help the development of scientific knowledge” (S6) |
| **Tentativeness**                                                                     |                                                                                       |
| Scientific explanation will not change, because “it will still based on the scientific explanation” (S2) | Scientific explanation can change, because “you can do an experiment everyday and there is no exception that that person can or cannot do so, that means whoever might have a chance to find a new explanation” (S2) |
| **Social aspects**                                                                    |                                                                                       |
| “social community can’t influence the development of science because social and science are irrelevant” (S1) | “Scientist should be teamwork, because if we have many people to develop it, it is sure (more confidential) than one person” (S1) |
| **Global Implication**                                                                |                                                                                       |
| “Knowledge of cellular respiration can’t be used to develop medicine for cancer” (S10) | Knowledge about cellular respiration can be utilized to develop medicine because “it is a process that occur in body, so it might be disease that relates to cellular respiration.” I don’t think it will affect one decision making, “because I’m a one person who know about it but don’t feel that I have to change what I do. I don’t mean that the process isn’t important with our body. No, it’s important, but I think it’s not going to affect us.” (S2) |

3.1. **Students’ NOS views prior to the intervention.**

The result of NOSQ prior to teaching intervention showed that majority of students posed naïve views regarding all targeted aspects of NOS as summarized in Table 1. The analysis on students’ responses shows that 67% could not explain the importance of empirical evidence in the development of scientific knowledge, 67% viewed that creativity should not be used in scientific endeavour as it can cause bias, 93% responded that scientific knowledge cannot change, 87% viewed that science is not a social enterprise, and 93% could not provide explanation on the influence of science to the society.

3.2. **Students NOS views post intervention.**

The result of NOSQ post intervention showed the improvement of students view on all targeted NOS aspects. The highest improvement is regarding tentativeness aspects NOS, in which 87% of students recognized the possibilities of changes when new knowledge is obtained, and 13% of students recognized the possibilities of changes when new data is obtained or when old data is interpreted in different way. Students’ responses regarding the use of creativity in science showed that 40% students hold informed views as they understood that creativity can be used not only in collecting data, but also in data interpretation. Majority of students’ responses regarding empirical evidence, were categorized as transitional view (73%) as they understood that scientific knowledge should be based on the empirical evidence which is obtained through experimentation or observation. However, they also provided responses which is inconsistent with contemporary accepted notion of the NOS. Similarly, majority of students’ response regarding social aspects and global implication of science are categorized as transitional (73%).
4. Discussion

The result of NOSQ prior to teaching intervention showed that majority of students posed naïve views regarding all targeted NOS aspects. It supported the report of many research documents that many students’ still understand NOS inadequately [2,8]. After the intervention, the result of NOSQ showed that students improved their views on NOS aspects, in which the highest improvement is regarding tentative nature of science and the use of creativity in science.

Majority of students viewed scientific explanation as persistent to change. As an example, S2 (see Table 2), viewed that scientific explanation will not change. Similarly, S1, also viewed that scientific explanation will not change because scientists already spent a long time to find the knowledge. After the teaching intervention, all students encouraged the possibilities of change in scientific explanation. However, majority of student only realized the possibilities of changes when new data is obtained (87%). The improvement of students views on tentativeness of science The improvement of students views on tentative nature of science, may relate to the implementation of The Hole Picture activities. In the activity, a coloured paper of certain shape is put inside a board with several holes on its surface. Students were directed to draw the shape of coloured paper inside the board. However, students can only see the shape of the coloured paper inside through several provided holes. After presenting their drawing, the students were given a chance to add more holes. When the clues they got from the new holes did not support the proposed shape they have drawn, students were given the chance to redraw a possible shape based the new clues they got. During the discussion, students were provided with explanation that the process of finding out the shape of coloured paper inside the box is analogous with the proses of researching the mechanism of cellular respiration which occurs inside the cell.

When analyzing the students’ responses on the other NOS aspects, including science is based on empirical evidence, science is a complex social activity, and science has global implications, the aspect of global implication of science appeared to be the least improved, particularly in relation to the concept of cellular respiration. Many students recognized that the knowledge of science, particularly cellular respiration, can give influence to the global society, such as the development of cancer treatment which had been influenced by the development of knowledge about cellular respiration process. However, many students could not recognize the possibility of cellular respiration knowledge to affect one’s personal decision making. The students viewed that their knowledge about cellular respiration is beneficial to enable them to understand the process which occur in their body, but it would not be necessary to influence their decision making.

The development of students NOS views in this study support the assertion of Vosniadou that “conceptual change, at least initially, is achieved gradually as constructive enrichment types of mechanisms are used, to add new but incompatible knowledge structures” [16]. Students who improved from naïve to transitional views on the aspects being addressed in this study represent a progress of a conceptual change process in the students. This study acknowledges the importance of activities which enable the students to enrich their understanding of NOS aspects in cellular respiration context. An example used in this study is The Hole Picture Activity followed by an explicit-reflective discussion regarding tentativeness nature in the development of knowledge about cellular respiration. If teachers are to integrate the teaching of science with NOS aspects, it is essential to provide such an activity in the fourth phase of teaching through conceptual change approach, which aims to raise the status of targeted NOS concepts.

5. Conclusion

In conclusion, the implementation of conceptual change approach in this study had been effective in improving students’ NOS views. Before the teaching intervention, majority of students’ posed naïve views regarding all targeted NOS aspects. After the teaching intervention, majority of students showed improvement on their NOS views, particularly regarding tentative nature of science and the use of creativity in science.

For researchers who are interested in integrating the teaching of science with NOS aspects, a further research can be conducted to compare various hands-on activities to raise the status of students...
NOS views in cellular respiration context, particularly regarding social aspect and global implication of science.

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