Improving Nos Understanding Through History Of Science Instruction: Contextualized Explicit And Reflective Approach

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ABSTRACT
The research objective of this study was to compare the relative effectiveness of history of science (HOS) integrated instruction and curriculum-oriented instruction on sixth grade students' understanding of nature of science (NOS). Accordingly, two classes were assigned to experimental group and other two were assigned to comparison group randomly. Experimental group was instructed by contextualized explicit and reflective approach in lessons that utilized history of science instruction on circulatory system while comparison group followed regular curricular activities suggested in national science curriculum. Both groups' NOS views were compared with pre, post and follow up measurements using VNOS-E. The result showed that, experimental group students' NOS views regarding targeted aspects improved in varying degrees after HOS instruction. The improvement in students' NOS views was discussed by attributing to contextualized, explicit and reflective NOS instruction.

Keywords: History of science, nature of science, contextualized instruction, explicit approach, reflective nature of science.

INTRODUCTION AND REVIEW OF RELATED LITERATURE
The development of students' understanding of nature of science (NOS) was emphasized as a major goal for science education (American Association for the Advancement of Science [AAAS], 1989; National Research Council [NRC], 1996). NOS has been conceptualized as "the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge" (Abd-El-Khalick, Bell, & Lederman, 1998, p. 418). Abd-El-Khalick et al. (1998) identified the characteristics of scientific knowledge as tentative (subject to change), empirically-based (based on and/or derived from observations of the natural world), subjective (theory-laden), partially based on human inference, imaginative and creative, socially and culturally embedded. Two additional aspects are the difference between observation and inference; and theories and laws.

There are few studies which explored students' NOS views at grade six level (Akerson & Abd-El-Khalick, 2005) and there is a need to explore elementary level students' understandings of NOS to help them develop their current views (Akerson & Abd-El-Khalick, 2005; Smith, Maclin, Houghton, & Hennessey, 2000), especially at an early age. Two main pedagogical approaches, namely implicit and explicit, have been used to develop students' NOS views by researchers (e.g. Abd-El-Khalick & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002). Implicit approach assumes that when students engaged in scientific inquiry-oriented activities, they will automatically come to realize NOS tenets. On the other hand, in explicit approach NOS is viewed as a cognitive objective which requires planning instruction to teach NOS (Khishfe & Abd-El-Khalick, 2002). The literature supports that implicit approach is not as effective as explicit approach in developing informed conceptions of NOS (e.g. Abd-El-Khalick & Lederman, 2000). Smith and colleagues (2000) found that students who were taught NOS explicitly developed more sophisticated understandings than students who were involved in implicit teaching of NOS. The study of Khishfe and Abd-El-Khalick (2002) also supported that six grade students who participated in implicit-inquiry oriented instruction could not develop informed views of NOS. In addition to implicit and explicit approach, reflective elements were integrated to explicit approach in which NOS aspects first introduced to students then opportunities were provided for students to reflect on their understanding of NOS (Abd-El-Khalick, Bell, & Lederman, 1998; Khishfe & Abd-El-Khalick, 2002). Clough (2006) argued that explicit and reflective approach can be contextualized or decontextualized. NOS activities such as black box or discrepant events are examples of decontextualized NOS instruction while contextualized NOS instruction emphasizes NOS aspects explicitly embedded within the science content. Clough argued that while decontextualized NOS instructions provide important opportunities for developing NOS understanding; deep understanding of NOS requires contextualized activities.

There are a number of studies pointing out that history of science (HOS) should be incorporated into science education to develop students' NOS conceptions (e.g. Clough, 2006; Klopfer & Cooley, 1963; Matthews, 1994). It was stated that "generalizations about how the scientific enterprise operates would be empty without concrete examples…Without historical examples, these generalizations would be no more than slogans" (AAAS, 1989, p. 111). NRC (1996) also emphasizes that "the historical perspective of scientific explanations demonstrates how scientific knowledge changes by evolving over time…" (p. 204). However Abd-El-Khalick and Lederman (2000) argued that HOS instruction alone cannot be sufficient to develop NOS understanding and emphasized that students' attention should be directed to NOS aspects explicitly.

In lights of the literature, this study investigated whether sixth grade students develop informed NOS views through incorporating contextualized explicit and reflective approach in lessons that use history of science. In this study, students' attention was explicitly drawn to target NOS aspects then opportunities were provided for students to reflect on their understanding of NOS through contextualized activities from the history of the circulatory system. Being a part of dissertation study, following overarching research question guided this work.

1. How do experimental and comparison group students' nature of science views of targeted aspects change from pre-instruction to post-instruction?

2. How do experimental and comparison group students' nature of science views of targeted aspects change from post-instruction to follow-up measurements?

METHODOLOGY

The subjects of this study consisted of 95 grade six students from four intact classes. Two classes were assigned randomly as experimental group (N = 51) and two as comparison group (N = 44). The comparison group received curriculum-oriented instruction (COI) for circulatory system while the experimental group received history of science incorporated curriculum-oriented instruction (called HOS instruction throughout this paper). Both groups' views were compared with pre, post and follow up measurements using Views on Nature of Science Elementary School Version [VNOS-E] (Lederman & Ko, 2004).

The first author instructed the experimental group because studies supported that even if classroom teachers have adequate NOS understanding, they are not able to teach NOS aspects to their students or they are not motivated to teach it (Akerson & Abd-El-Khalick, 2003; Bell, Lederman, & Abd-El Khalick, 2000). The comparison group was instructed by their science teacher. Every effort (e.g. preparing lesson plans together and observing each other's practice, habituating the classroom before implementation) was undertaken to ensure that the teacher and the researcher implemented content-specific activities in the same way to the extent possible.

The historical materials developed for this study aimed to reveal how the knowledge of circulatory system evolved from ancient times to the present. Specifically how the function of heart was understood by different scientists and different societies, how the invention of microscope led to the development of knowledge on constituents of blood, how the blood transfusion developed throughout the history, and how the physiology of blood circulation was interpreted by different scientists (e.g. Galen and Harvey's Theory of Blood Circulation) were addressed. By means of historical materials, different aspects of NOS were emphasized. The historical materials were introduced in four phase. In the first phase students were engaged in specific historical document. Students studied the material either individually or as a small group (i.e. *Experiencing Historical Material*). In the second phase, handouts, containing probing questions about related historical material, were provided to students. The goal of this phase was to make them prepared for the next phase and organize their thoughts with reference to historical materials at hand (i.e. *Engaging in Probing Questions*). The aim of third phase was to provide students an open space to share their opinions with historical evidences. Students presented their ideas, elaborated others thoughts, challenged with counterclaims and provided evidence from historical material (i.e. *Whole Class Discussion*). In the last phase, students were guided to generalize the central historical material to the complex epistemology of science. In this phase, it was intended that students develop an appreciation of nature of science through making connections between the specific historical activity and scientific enterprise (i.e. *Creating Generalization*).

In order to investigate participants NOS views, a rubric was developed by two independent researchers. An inter-rater reliability analysis using the Kappa statistic was performed to determine consistency among researchers. The Kappa measure of agreement value was .78 with $p < .001$. The inter-rater reliability is statistically significant and met the expectations for reliable assessment (Landis & Koch, 1977). In this rubric, students' NOS views were categorized as "naïve" "transitional" and "informed". Data analysis was performed through descriptive statistics and McNemar Test. The results were supported with qualitative data as well.

RESULT

In this study students' understanding of five aspects of NOS (i.e. *empirically based*; *tentative; subjective; creative* and *imaginative,* and *inferential)* were aimed to be developed. For this specified purpose, participants' NOS views were compared at each consecutive time of testing for each group. In other words, participants' pre-post and post-follow up NOS understandings were compared within each group separately. In a general sense, the result showed that experimental group students' NOS views regarding aforementioned aspects were improved in varying degrees after HOS instruction. They also articulated similar views when compared their follow-up views with post-instruction views. On the other hand, comparison group could not develop informed views of NOS during the course of the study. Table 1 summarizes the overall results found in this study.

Table 1. Overall summary of within group comparisons regarding targeted NOS aspects.

Aspect	Time Pair	Group	Naive	Transitional	Informed
Tentative	Time 1-Time 2	Experimental	↓	↔	↔
		Comparison	↔	↔	↔
	Time 2-Time 3	Experimental	↔	↔	↔
		Comparison	↔	↔	↔
Subjective	Time 1-Time 2	Experimental	↓	↔	↑
		Comparison	↔	↔	↔
	Time 2-Time 3	Experimental	↔	↔	↔
		Comparison	↔	↔	↔
Empirical	Time 1-Time 2	Experimental	↔	↓	↑
		Comparison	↔	↔	↔
	Time 2-Time 3	Experimental	↔	↔	↔
		Comparison	↔	↔	↔
Creative and Imaginative	Time 1-Time 2	Experimental	↔	↔	↑
		Comparison	↔	↔	↔
	Time 2-Time 3	Experimental	↔	↔	↔
		Comparison	↔	↔	↔
Inferential	Time 1-Time 2	Experimental	↓	↑	↑
		Comparison	↔	↔	↔
	Time 2-Time 3	Experimental	↔	↔	↔
		Comparison	↔	↔	↔

Note: In Table 1, "↓" refers to statistically significant decrease; "↔" refers to statistically non-significant change; "↑" refers to statistically significant increase, based on McNemar Test result.

As represented in Table 1, the proportion of participants in experimental group who exhibited a naïve view about tentative aspect of NOS changed significantly right after HOS instruction, $\chi^2 = 5.88$, $p = .013$. Participants were more likely expressed naïve views before HOS instruction (52%) than after HOS instruction (29%). The following quote pairs exemplify how participants' tentative views change before and after HOS instruction.

> ***Student A before HOS instruction:*** *... Science is to come up with an invention. In science, scientists make various inventions in different areas... I don't think what scientists know will change in the future.*
>
> ***Student A after HOS instruction:*** *Science is any attempt in which scientists try to find new and different knowledge about a topic... I believe that scientists conduct study in order to modify or change what they know at present… Yes, every scientific knowledge is subject to change.*

Before HOS instruction, participant A elucidated naïve views while s/he articulated informed views after the instruction regarding tentative aspect of NOS. Before the instruction s/he seemed to believe that scientists invent the things around us. S/he also explicitly underlined that scientific knowledge is not subject to change. But after HOS instruction, s/he could perceive that science has evolutionary characteristics, therefore s/he stated that every scientific knowledge is subject to change.

The proportion of participants in comparison group who held naïve ($\chi^2 = .21$, $p = .648$), transitional ($\chi^2 = .00$, $p = 1.000$), and informed views ($\chi^2 = .17$, $p = .687$) about tentative aspect of NOS did not change significantly from pre- to post-instruction. The following quote pairs show how comparison group participants' views on tentative aspect were consistent from pre- to post-instruction.

> ***Student B before COI instruction****: There are always realities in science and scientific knowledge is proven by research and experiments...*

> ***Student B after COI instruction:*** *Science covers everything, at least partly. By the help of scientific methods scientists can prove scientific knowledge and find the realities.*

In terms of subjective aspect, the proportion of participants in experimental group who held naïve views decreased significantly (40% to 17%) right after HOS instruction, $\chi^2 = 5.26$, $p = .019$. Moreover, there was a significant change in the proportion of participants who demonstrated an informed subjective views after HOS instruction, $\chi^2 = 7.68$, $p = .004$. Participants were more likely in informed level after HOS instruction (48%) than before HOS instruction (19%). The following quotes pair illustrates how experimental group participants' views about subjective aspect of NOS changed after HOS instruction.

> ***Student C before HOS instruction:*** *The trace and the fossil of each dinosaur are different from each other. Therefore the fossils they [scientists] are working on belong to different dinosaurs. So, they disagree about them [dinosaurs' extinction].*

> ***Student C after HOS instruction:*** *Each scientist has different point of view. They are interpreting the evidence based on it. That is why they don't agree with each other about the reason why dinosaurs disappeared.*

The proportion of participants in comparison group who held naïve ($\chi^2 = .21$, $p = .648$), transitional ($\chi^2 = .00$, $p = 1.000$), and informed views ($\chi^2 = .36$, $p = .549$) about subjective aspect of NOS did not change significantly from pre to post-instruction. Following quotes pairs exemplify representative responses of students in comparison group regarding subjective aspect.

> ***Student D before COI instruction****: Dinosaurs are appearing on TV, so scientists could gather information about them from TVs. They [scientists] might collect information from computers too. Therefore they [scientists] know that dinosaurs lived on the Earth... Weather people are sure about weather pictures because they [weather people] obtain that information from scientists.*

> ***Student D after COI instruction:*** *Scientists collect information about dinosaurs from TVs, other people, and computers. Therefore they [scientists] know that dinosaurs' survived in ancient times... Weather people are 100% sure about weather picture because they broadcast the report of experts and scientists.*

It was evident in Student D's responses that her/his views about subjectivity in scientific endeavor was durable from first to next measurements. In other words COI did not lead her/his subjective NOS views to develop.

Regarding empirical aspect of NOS, the proportion of participants whose response revealed a transitional view changed significantly before and after HOS instruction ($\chi^2 = 9.38$, $p = .002$). Participants more likely exhibited a transitional views before HOS instruction (50%) than after HOS instruction (17%). There was also a significant change in the proportion of participants who elucidated informed views ($\chi^2 = 16.53$, $p < .0005$). Participants were more prone to appreciate the role of empirical evidence in science after HOS instruction (75%) than before HOS instruction (25%). The following quotes show how the participants' views on empirical aspect changed from pre- to post-instruction in experimental group.

> ***Student E before HOS instruction:*** *Science is arising from mental thoughts of a person... Science is different from other subjects because science is the accumulations of those thoughts. There are also some thoughts in other subject but they are limited.*

> ***Student E after HOS instruction:*** *Scientists always reasons about situations. In science people do research, observe the nature, and conduct experiment on scientific topics. This is the difference between science and other topics.*

Student E could not make a distinction between science and other disciplines in terms empirical based nature of science before the instruction. After HOS instruction, however, s/he could acknowledge that science is different from other disciplines due to its empirical nature and s/he referred to the observation, research, and experiments in science.

Consistently, there was not a significant change in the proportion of participants who expressed naïve views ($\chi^2 = 2.50$, $p = .109$); transitional views ($\chi^2 = .31$, $p = .581$); and informed views ($\chi^2 = .36$, $p = .549$) after COI when compared with proportion of participants before COI. The following quote pairs show how the participants' view on empirical aspect was consistent from pre- to post-instruction in comparison group.

> ***Student F before COI instruction****: Science is one of our courses in the school. Others, for example literature and art, are also courses in the school. I mean no difference exist between science and others.*

> ***Student F after COI instruction:*** *There is nothing that makes science different from other school courses. They are all one of the school subjects and they are all identical…*

Student F failed to understand the empirical nature of science before and after COI. In her/his response to the second questionnaire item about the distinction between science and other subjects, s/he could not differentiate science from other disciplines by taking into account the empirical nature of science. S/he considered science as a school subject in both measurements.

In terms of creative and imaginative tenets of NOS, there was a significant increase in the proportion of participants who articulated informed views after HOS instruction, $\chi^2 = 4.5$, $p = .031$. Before HOS instruction, only 25% of all participants in experimental group articulated informed views. However, almost half of the participants (46%) expressed informed views after HOS instruction. The following quote pairs show how the participants' views on creative and imaginative aspect developed from pre- to post-instruction in experimental group.

> ***Student G before HOS instruction:*** *Scientists have conducted scientific research; therefore they are sure about dinosaurs' appearance... No I don't think that scientists use their imaginations when they do their work. They inform us about the knowledge they obtain. If they incorporated it [creativity and imagination] into their work, then we would have incorrect knowledge.*

> ***Student G after HOS instruction:*** *Scientists may not be exactly sure about dinosaurs' appearance. On the one hand, they [scientists] seem to be created dinosaurs' appearance. On the other hand it was reported that they once lived on the Earth through photography and etc.... Yes I believe that scientists use their imagination... I think that scientists utilize creativity and imagination during the beginning of any scientific study.*

Before HOS instruction, student G elucidated naïve views regarding creative and imaginative NOS. S/he seemed to believe that scientists know about dinosaurs because they conduct scientific research. S/he did not make any reference to the role of creativity and imagination in science. S/he also explicitly stated that creativity and imagination would make scientists to arrive wrong conclusions. But after HOS instruction, s/he articulated transitional views regarding the same aspect. S/he seemed to have undecided about the role of creativity and imagination in science. S/he could not decide whether scientists use their creativity or whether they only report what they see. S/he also stated that early stage of scientific investigations include those skills.

In comparison group, the proportion of participants who demonstrated naïve ($\chi^2 = 2.12$, $p = .143$), transitional ($\chi^2 = 1.89$, $p = .167$), and informed views ($\chi^2 = .00$, $p = 1.000$) about creative and imaginative aspect of NOS did not change significantly from pre- to post-instruction. Following quote pair demonstrates one of the students' views before and after COI. It was evident in those students' responses that comparison group students could not make progress in their views regarding creative and imaginative NOS after the instruction.

> ***Student H before COI instruction****: … Yes. Scientists use their imagination in planning and in conducting experiments. By this way they decided on how to precede their work. But scientists are supposed to be objective in other phases such as reporting their result...*

> ***Student H after COI instruction:*** *Of course scientists use their creativity and imagination in their study. They hypothesize what to research and then conduct their experiments. I think they use their imagination during stating hypothesis and their creativity during experiments. But final part should be imaginative and creativity free...*

Before the instruction student H expressed that scientists use their imagination and creativity only in some particular phase of their studies, planning and conducting experiments. After the instruction, s/he accepted the role of creativity and imagination as well; but stated that scientists use them only during hypothesizing and conducting experiments. In short, s/he expressed transitional views on both measurements.

Regarding inferential aspect of NOS, the proportion of participants in experimental group who held naïve views, ($\chi^2 = 16.06$, $p < .0005$); transitional views, ($\chi^2 = 4.50$, $p = .031$); and informed views, ($\chi^2 = 4.90$, $p = .021$) changed significantly right after HOS instruction. The proportion of participants holding naïve views decreased, while the proportion of participants articulating transitional and informed views increased right after the HOS instruction. Before the instruction, while 36 (75%) students held naïve views; 18 (38%) students expressed naïve views after HOS instruction. Only 7 (15%) students articulated transitional views before the instruction. This number increased to 17 (35%) after HOS instruction. Compared to 5 (10%) students prior to instruction, the number of students who articulated informed views increased to 13 (27%) after HOS instruction. The following quotes show how the participants' views on inferential aspect of NOS developed from pre to post-instruction in experimental group.

> ***Student I before HOS instruction:*** *Scientists are certain about it [the way dinosaurs looked]... Dinosaurs' traces reveal their appearance.*
>
> ***Student I after HOS instruction:*** *By combining the parts of skeleton, scientists created possible appearance of dinosaurs. In this way they gained knowledge [about dinosaurs' appearance]. I think they are not sure about it because those shapes are scientists' own design.*

It was also evident in the following student's (E27) response that experimental group student could expressed more adequate understanding about the distinction between observation and inference after HOS instruction.

> ***Student J before HOS instruction:*** *They [scientists] are not totally sure about the way dinosaurs looked. Because they [scientists] didn't see them [dinosaurs].*
>
> ***Student J after HOS instruction:*** *They [scientists] are struggling to join the different fossils of dinosaurs together. Scientists don't have all the information about them. Based on what they have, they are trying to estimate their appearance.*

This students (Student J) articulated naïve and informed views before and after HOS instruction respectively. Before the instruction, s/he held the stereotypic naïve conception that "knowing is seeing". After HOS instruction, however, s/he could demonstrate informed understanding of the distinction between observation and inference in the construction of scientific explanations. In her/his post response, s/he referred that scientists are attempting to estimate dinosaurs' appearance (inference) based on studying ever found dinosaurs' fossils (observation).

For the comparison group, the proportion of participants who held naïve (χ^2 = .27, p = .607), transitional (χ^2 = .17, p = .687), and informed views (χ^2 = .00, p = 1.000) about inferential aspect of NOS did not change significantly from pre to post-instruction. The following quote pairs show how the participants' view on inferential aspect was consistent from pre- to post-instruction in comparison group. Participant K expressed naïve views before and after curriculum-oriented instruction.

> ***Student K before COI instruction****: ...by analyzing the bones of dinosaurs which dates from past, they [scientists] have had information about their [dinosaurs] existence on the Earth... They [scientists] are conducting DNA tests on the bones [fossils] of dinosaurs. By this way, they obtain their appearance accurately.*
>
> ***Student K after COI instruction****: Geologists found the traces of dinosaurs under the soil and scientists analyze them in the laboratories. They have discovered their existence by this way... They [scientists] also examined their DNA sequence and found how they [dinosaurs] appeared.*

Students K believed that direct evidence is the only source of scientific knowledge and nothing else is relevant to scientific explanations. Her/his response illustrated her/his understanding of science as strictly evidence based. S/he could not demonstrate an understanding that scientists inferred the way dinosaurs looked by grounding their inference to fossils of dinosaurs. In brief, s/he could not demonstrate an adequate understanding of the distinction between observation and inference at both measurements.

So far, students' pre- and post-instruction views on targeted NOS aspects were compared. Based on this evaluation, results indicated that students in experimental group revealed better understanding in all targeted aspects of NOS after receiving HOS instruction. Comparison group students, on the other hand, did not show any improvement about these aspects after getting curriculum-oriented instruction as expected.

When experimental group students' post and follow-up NOS views were compared within the group, it was found that they expressed quite similar responses to the VNOS-E items at both measurements. Moreover, comparison group students articulated quite similar responses at post and follow-up measurements too. This means that both groups retained their post views five weeks after the instructions.

DISCUSSION

This study investigated the influence of HOS instruction including contextualized explicit and reflective NOS discussions on students' understanding of NOS views. The results revealed that students involved in HOS instruction developed informed conceptions of NOS. This study provided empirical evidence for the influence of HOS instruction on the development of NOS views among grade six students. Khishfe and Abd-El-Khalick (2002) pointed out to the lack of research on explicit and reflective approach among younger students because most studies investigated science teachers' understanding of NOS. The improvement in students' NOS views can be attributed to contextualized, explicit and reflective NOS instruction. Clough (2006) argued that decontextualized NOS instruction is not adequate to develop NOS understanding. He further stated that contextualizing NOS through "integrating historical and contemporary science examples that are tied to the fundamental ideas taught in particular science subjects. Such examples illustrate the complexities and challenges individual scientists and the scientific community experience in constructing ideas and determining their fit with empirical evidence" (Clough, 2006, p, 474). The incorporation of history of science supports students to further develop and acknowledge adequate NOS understandings. This study implies that HOS should be a part of science education to draw students' attention to the development of scientific knowledge.

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