Educational Sciences: Theory & Practice - 12(2) • Spring • 1107-1113
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www.edam.com.tr/estp

The Effectiveness of the Conceptual Change Approach, Explicit Reflective Approach, and Course Book by the Ministry of Education on the Views of the Nature of Science and Conceptual Change in Light Unit*

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Abstract

The aim of this study was to analyze the effectiveness of the conceptual change approach, explicit reflective approach, and the course book by the Ministry of Education on the views toward the nature of science and conceptual change in the Light unit. Three study groups were selected from several seventh grade classes. Two of the three classes, including 22 students, were assigned to participate in the experimental study group and the other was assigned as a control group. A conceptual change approach was used in one of the groups, whereas explicit reflective approach was used in the other one. An open-ended questionnaire on the views of nature of science in conjunction with semi-structured interviews, and the Conceptual Test of Light Unit were used to collect the data. The students' views toward the nature of science were analysed in informed, transitional, and naive categories. The Kruskall-Wallis Test and Wilcoxon signed-rank test were used for the analysis of the conceptual test data. It was determined that the most effective way to teach the nature of science was the conceptual change approach. Three teaching methods contributed positively to the conceptual change about light, but it was found out that the effects of course book of Ministry of Education were not long term. It is recommended that the conceptual change text and concept clipboards should be used together in teaching the nature of science.

Key Words

Nature of Science, Conceptual Change Text, Concept Clipboard, Explicit Reflective Approach, and Light.

One of the most important aims of science education is to help students comprehend the nature of science (NOS). This purpose holds a central place in science education policies (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996) as well as in the science curricula in many countries (e.g., Australia, Canada, England, New Zealand, Turkey, US, and Zambia). But, NOS education is not given importance in schools (Karakaş, 2009; Kattoula, Verma, & Martin-Hansen, 2009). Moreover, the science education that is practiced in schools is inadequate and does not enable students to understand contemporary views on the NOS. This lack of understanding contributes to the development of alternative concepts (Ibanez-Orcajo & Martinez-Aznar, 2007; McComas, 1996, 2000; Rannikmae, Rannikmae, & Holbrook, 2006). Typically, NOS refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge (Lederman, 1992). It has been stated that primary school students can

* This research is part of the primary author's doctoral dissertation.

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understand tentative, empirical, imaginative, creative, and inferential aspects of NOS. For this reason, we discuss these four aspects of NOS in this study (NRC, 1996; Milli Eğitim Bakanlığı [MEB], 2006).

The studies conducted revealed that the students at different learning levels (Dawkins & Dickerson, 2003; Kang, Scharman, & Noh, 2005; Parker, Krockover, Lasher-Trapp, & Eichinger, 2008), the teachers, and the prospective teachers (Abd-El-Khalick & Lederman, 2000b; Buaraphan & Sung-Ong, 2009; Chin, 2005; İrez, Çakır, & Doğan, 2006; Yalvaç, Tekkaya, Çakıroğlu, & Kahyaoğlu, 2007) had a naive/inadequate view of NOS, and they had misconceptions about some concepts. This led us to determine that NOS is inadequately understood, which raised the question of how this subject can be effectively taught. Additionally, studies have revealed that the explicit reflective approach is the most effective way of teaching the NOS (Lederman, 2006), but this approach is also insufficient in teaching some aspects of the NOS (Akerson, Morrison, & McDuffie, 2006; Çelik & Bayrakçeken, 2006; Dagher, Brickhouse, Shipman, & Letts, 2004). Consequently, new expansions of the explicit reflective approach are needed to increase its efficacy. One such expansion is conceptual change philosophy (Abd-El-Khalick & Lederman, 2000a; Khishfe & Abd-El-Khalick, 2002). It was seen that NOS education has experimented with various techniques and models of conceptual change (Abd-El Khalick & Akerson, 2004; Biernacka, 2006; Kattoula et al., 2009; Mumba, Carver, Chabalengula, & Hunter, 2009). Conceptual change text (CCT) is one of the best ways for achievement conceptual change.

The approach, CCT, supports conceptual change by activating students' alternative concepts, stimulating dissatisfaction with their previous knowledge, and trying to convince the students for the scientific knowledge in a plausible and understandable way (Alkhawaldeh, 2007; Özmen, 2007; Roth, 1985; Yürük, 2007). However, as of yet, there are a limited number of studies about the use of CCT for teaching NOS.

Because many qualities of light require abstract thinking to understand, it is one of the more difficult subjects to teach as well as learn (Eshach, 2003; Galili & Hazan, 2000; Sprod & Jones, 1996; Warwick & Stephenson, 2002; Yalçın, Altun, Turgut, & Aggül, 2009). Because of this, we decided that the study was to be conducted within the context of the Light unit. The NOS CCTs and explicit reflective approach activities are compatible in the context of teaching the Light unit we thought that it was necessary for the instructions to analyse the effects of conceptual change about light. Conceptual change is inconsistently defined in the literatüre. In this study, conceptual change is based on Hewson's (1992) point of view. Hewson believes in completely changing the ideas present in the students' minds, correcting the wrong pre- knowledge that the students had, reaching the explanations that are accepted as scientifically true, acquiring the missing concepts, and going for a new cognitive restructuring.

After the implementation of each CCT, the students were asked to prepare responses giving free reign to their creativity, such as poems, cartoons, tongue twisters and riddles that related to aspects of the NOS being studied. Students products were exhibited on the wall in class. We referred to this practice as the *concept clipboard*. The use of concept maps (Kattoula et al., 2009; Kim, Germann, & Patton, 1998), roundhouse diagrams, and poster preparation (Doğan, Çakıroğlu, Bilican, & Çavuş, 2009) for teaching the NOS is found in the literature. However, the concept clipboard is not often used in NOS education. The present study is intended to present some insights regarding whether or not the concept clipboard supports NOS education.

The NOS was taught to the students through three different teaching materials in this study. One of them was the conceptual change approach; one was explicit reflective approach; and the third was the course book used in schools by Ministry of Education. This primary aim of this study was to analyze the effects of these three teaching methods. Secondary goals of the study are given below:

1. To evaluate how these three different teaching methods affected the students' views of NOS and the retention of the effects.
2. To study the effects of these three teaching methods related to conceptual change in the Light unit and its effects on the retention of this change.

Method

Research Design

A mixed methodology was used in this study (Creswell, 1994). When comparing the effects of the three different types of instruction, the study shows compatibility with the *pre-test, post-test,* and *non-equivalent group design* of the quasi experimental method (Çepni, 2010). Moreover, because the meanings the students ascribed to the aspects of NOS and the concepts mentioned in the Light unit were focused on, the study was also an *interpretive* research project (LeCompte & Preissle, 1993).

Sampling

The study was conducted in a city that is located on the coast of the Black Sea in Turkey in a state school that has a middle-level, socioeconomic student body. The school has four seventh-grade classes (from the age of 12 to 14). Two of the classes were selected randomly as experimental groups (one of them was taught the NOS with conceptual change approach and the other one was taught with explicit reflective approach); the other one was chosen as the control group (the book of Ministry of Education was used). The study was conducted with a total of 66 students; each class was composed of 22 students.

Measures

An open-ended questionnaire in conjunction with semi-structured interviews was used to assess participants NOS views. A total of twelve participants (55%) each group was interviewed (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). The data related to the subsequent secondary aim were collected with the Light unit conceptual test, which was developed by the researchers. The test, which was made up of 14 questions, was prepared in the format of a two-tiered concept test. The content reliability of the test was provided with the views six experts (Al Khawaldeh & Al Olaimat, 2009; Taştan, Yalçınkaya, & Boz, 2008; Yürük, 2007). The Cronbach Alpha of the test was calculated as .75 (You can see Çil, (2010) for the details of data collection tools).

Process

1. The data collection tools were applied as a pre-test before teaching. The teaching of the unit lasted 18 class periods (each lesson was 40 minutes).

2. CCT are made up of five sections. The method begins with a question that aims to reveal the students' views about certain aspects of the NOS. After the students answered the questions in this section, they discussed their views with their peers. After these discussions, the second part of CCT was conducted. In this section, the unscientific explanations focused on NOS aspect and why they were not true were emphasized. In the third phase, the scientific explanation of the question was presented. The aim of the first three parts of CCT was to reveal the prior knowledge of the students, to create cognitive disequilibrium, and to cause the students to become dissatisfied with their existing knowledge (Hynd, 2001; Khishfe & Abd-El-Khalick, 2002; Posner, Strike, Hewson, & Gertzog, 1982). The fourth part of CCT aimed to introduce and teach contemporary concepts related to NOS (Alkhawaldeh, 2007; Özmen, 2007; Roth, 1985; Yürük, 2007). This part was made up of science activities about light. For example, the fourth section of CCT focuses on the inferential aspect of NOS. To complete the exercise, the students took on the role of police investigating a crime scene during which they collected evidence of a forest fire and prepared a report about the reasons of the fire. The students did research and experiments related to each reason they put forward about the fire's cause. In the last part of the CCT (called Let's Get to a Conclusion), there are questions about the NOS and the science content. For example, in the last part of CCT which was mentioned above, answers to the following questions were sought: Did you see what caused the fire?, "How did you decide upon the reasons of the fire?, "How did the scientists decide the physical qualities of the dinosaurs which existed millions of years ago?. The students first answered these questions individually, and then a whole-class discussion was carried out. Within the context of the study, eight NOS CCTs were implemented. After each CCT, the students were asked to prepare a poem, caricature, picture, riddles, and so on about the acquisition of the element of NOS dealt with and the acquisition of light unit. *The Concept Clipboard of NOS* was formed with these products.

3. The activities of the explicit reflective approach begin with a research question. The research questions were about light. For example, in an activity that focused on the creative aspect of the NOS, the students were asked the question, "does the diffusion speed of light beams depend on the type of transparent environment where it is diffused?" In the second stage, the

students did experiments in small groups of four or five people in order to find an answer to the research question. They then analyzed the data they collected. In the final stage, a whole-class discussion was carried out on the specific aspect of the NOS. For instance, in an activity that dealt with the creative aspect of the NOS, there were several questions: "Could you calculate the diffusion speed of light in transparent environments such as air and water?", "How did you decide in which environment the light diffused faster?", "According to you in which environment does the light diffuse faster, glass or water?". Moreover a whole class discussion was carried out about topics such as how the universe formed, why dinosaurs became extinct, and how the structure of an atom was decided upon. Finally, a reflective written homework was assigned about the aspects of NOS, which were focused on in the activity. All of these that we aimed to the students were encouraged to reflect, both orally and in writing, on aspects of NOS (Abd-El-Khalick & Akerson, 2004; Akerson, Abd-El-Khalick, & Lederman, 2000; Khisfe & Abd-El-Khalick, 2002). During the teaching process, eight explicit reflective approach activities were used.

4. There are no activities about the teaching of the NOS in the Light unit of the course book of Ministry of Education. Because of this, teaching NOS was carried out with implicit approach in this group (Abd-El-Khalick & Lederman, 2000a).

5. Completing the education a week later, the data collection tools were used as the post-test. Eight weeks after the instruction was completed the data collection tools were applied as delayed test in order to determine the retention of the effects of the instructions carried out.

Results

The students' views about the aspects of NOS were classified as naive, transitional, or informed in accordance with the terminology developed by Khishfe and Lederman (2006). Before receiving instruction, most of the students in each group had transitional views about the tentative, empirical, and creative aspects of the NOS. Roughly 55–86% of the students didn't know the difference between observation and inference. They believed that to know something is simply to observe it. The explicit reflective approach showed a 30% increase pertaining to informed views for the tentative and empirical aspects of the NOS. The informed views for the creative and inferential aspects of the NOS dealt within the context of the study are only 15 %. The informed views in a group who were taught with the conceptual change approach increased 60% for the tentative aspect of the NOS, 50% for the empirical aspect of the NOS, 30% for the creative aspect of the NOS, and 5% for the inferential aspect of the NOS. The changes that did not reach 10% after teaching were in the group where the course book of Ministry of Education was used.

The data related to the students' conceptual changes about light were evaluated by SPSS 17 program using Kruskall-Wallis Test, and Wilcoxon signed-rank test (Shavelson, 1988). When the grades the groups got from the Light unit concept test before the instruction were compared with Kruskall-Wallis Test, it was calculated as $p > .05$ ($p = .31$). When the results obtained from the application of post-test of Concept Test were compared, it was again $p > .05$ ($p = .21$). Eight weeks later after the instruction was completed, meaningful differences between the students' conceptual changes were determined ($p = .05$). After the mean rank values had been analysed, it was found out that the difference was in favour of conceptual change group. According to the Wilcoxon signed rank test, there are meaningful differences in all the groups between the pre-and post-tests (for experiment groups, $p = .00$ and $p = .02$, for control group $p = .03$). There is no meaningful difference between post and delayed test ($p = .31$ and $p = .19$) with the groups who learned the NOS with conceptual change and explicit reflective approaches. However, there are meaningful differences between the pre and the delayed test, which is in favour of the delayed test ($p = .00$ and $p = .01$). When the grades of post and delayed tests were compared for the groups who were taught with the course book of Ministry of Education, a meaningful difference was determined in favour of the post-test ($p = .04$). There is no meaningful difference between pre-and delayed tests ($p = .18$).

Discussion

Before receiving instruction, most of the participants had transitional views of the tentative, empirical, and creative aspects of the NOS. They also had naive understandings of the distinction between observation and inference. This negative table continued during the post and delayed tests for the groups that used the course book of the Ministry of Education. These results show similarity with study results in the literature (Çelikdemir, 2006; Kang et al., 2005; Muşlu & Macaroğlu-Akgül; 2006; Yiğit, Alev, Akşan, & Ursavaş, 2010). Students start formal science instruction in the fourth grade (at the age of 10) in Turkey. Although the students participating in the study had three years' experience in science instruction, the unsuccessful results of the pre-test may mean that the current science education curriculum is not effective in enabling students to acquire a contemporary understanding of the NOS.

The explicit reflective approach made important contributions for the understanding of tentative and empirical aspects of the NOS. It was determined that the explicit reflective approach created a limited effect for the creative and inferential aspects of the NOS. These results show similarity with study results in the literature (Khishfe & Abd-El-Khalick, 2002; Khisfe & Lederman, 2006; Lewthwaite, 2007; Metin, 2009; Veal, 2004).

It was determined that the conceptual change approach was the most effective way to teach the NOS. The conceptual change approach was also found out to help students retain new views. It was determined that in literature some models of the conceptual change method gave positive results in teaching of the NOS (Abd-El Khalick & Akerson, 2004; Biernacka, 2006; Mumba et al., 2009). The most important reason of these positive results may be CCT. Presenting scientific knowledge to students in clear and easily understandable language was not sufficient to explain the misconceptions that existed in their minds (Çetingül & Geban, 2005; Guzzetti, 2000; Hewson, 1992; Roth, 1985). When students realized that their prior knowledge was inadequate and they became dissatisfied with this prior knowledge, they would take action to change it (Liao & She, 2009; Posner et al., 1982; Shepardson, Moje, & Kennard-McClelland, 1994). Some students, especially those who had difficulty reading, couldn't benefit much from the CCTs (Guzzetti, 2000; Köse & Uşak, 2007; Pınarbaşı, Capolat, Bayrakçeken, & Geban, 2006). It was argued that visual materials and models benefitted such students by decreasing the writing intensity and drawing their attention to the text (Canpolat, Pınarbaşı, Bayrakçeken, & Geban, 2006; Köse, Kaya, Gezer, & Kaya, 2011). Almost every section of the NOS CCTs that was used within the context of this study benefited from the integration of visual materials, such as pictures, tables, diagrams, and graphics. It was observed that the students expressed their opinions by referring to these visuals in the post- and delayed tests. In this context, it could be said that the visuals used in CCTs were attractive to the students, motivated the students to read them, and contributed to the students' understanding of the message being given. Another reason for the positive results achieved in the class may be the concept clipboard of the NOS. Students' citation of examples from the concept clipboards when they expressed their opinions in the questionnaire and the interviews seemed to support this opinion. Despite all these positive results, nearly half of the students couldn't understand the creative and inferential aspects of the NOS. It could be concluded that the primary school students emphasized the points at which the scientists were required to be physically active in obtaining scientific knowledge, but they neglected the mental processes used by scientists. This situation occurs because the students have not reached the formal operational stage. Students above the age of 11–12 are expected to have moved beyond the formal operational period. However, it has been determined in the literature that students in this age group are not able to engage in formal operational thinking (Berninger & Yates; 1993; Endler & Bond, 2008; White, 2006).

Teaching in each of the three groups contributed positively to the conceptual change in the Light unit. But, the retention of the course book of Ministry of Education was not effective. The positive results in experimental groups may result from instruction of the NOS, because CCTs and explicit reflective approach activities are compatible in the Light unit context. In the current study post-test scores indicate that the control group improves their conceptual understanding about light. The new science curriculum in Turkey is based on constructivism and student-centred teaching. The basic cause for this positive change in control group may be the constructivist learning environment (Akkuş, Kadayıfçı, Atasoy, & Geban, 2003; Bukova-Güzel, 2007; Çalık, Ayas, Coll, Ünal, & Coştu, 2007). However students returned their initial conceptions overtime. One of the main reasons for this situation may be course books are not fully compatible with constructivist learning philosophy.

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