ORIGINAL ARTICLE

The Effect of Hot Conceptual Change on Students’ Views on the Nature of Science‡

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***Abstract**: This study aims to investigate the effect of the teaching model developed for hot conceptual change on middle school 7th-grade students’ understanding of the Nature of Science (NOS) aspects. In this qualitative and exploratory study, activities were carried out with 24 students of two classes in a village school in the South Marmara region using a pretest-posttest control group quasi-experimental design. Students in control (inquiry-based learning-IBL) and experimental (hot conceptual change based on IBL) groups used instructions for teaching the NOS topics in the 7th-grade light unit. The pre-test and post-test data on the NOS were obtained by the Opinions on the Nature of Science Questionnaire (ONSQ). In the analysis of ONSQ data, students’ views on the aspects of the NOS were scored according to the adequate (3), variable (2), and weak (1) categories. These scores were converted into gain scores and considered in the comparison between the groups regarding those aspects. Semi-structured interviews were conducted with two students from each group before and after the implementation. The gains related to NOS aspects obtained with the instructions carried out for seven weeks were presented and results were discussed in the context of the literature on hot conceptual change, IBL, and NOS. Finally, suggestions were made for new research and teaching practices for teachers.*

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Introduction

SCIENCE literacy is important for children to understand what is scientific or non-scientific. For this purpose, important steps have been taken and innovations have been made in science curricula in Turkey in the last 10 years (Ministry of National Education, 2013; 2017; 2018).

One of the important subcomponents of science literacy skill is the nature of science (NOS), a very popular subject area in the literature (Akerson et al., 2000; Lederman, 2007). This subject area is the key point in understanding science (Lederman, 1992; McComas & Olson, 2004). In addition, learning NOS positively affects the teaching of science concepts (Abd-El-Khalick & Lederman, 2000; Chaiyabang & Thathong, 2014; Papadouris & Constantinou, 2011; Papadouris & Constantinou, 2014; Michel & Neumann, 2016).

The Nature of Science Aspects

Defining the nature of science is difficult due to the problems experienced in defining the concept of science. On the other hand, there is a consensus on the definitions of the nature of science, except for minor disagreements (Abd-El-Khalick, 2005; Ledermen, 2007; McComas, 2004; Ozcan, 2013). Although McComas (2002) considers these definitions as 14 aspects in his study, at the secondary education level, these headings can be increased or decreased according to students' grade level. Cil (2010), in her experimental study conducted with 7th-grade secondary school students, addresses the common aspects in accordance with the age level. These were; defining science (1), the provisional nature of scientific knowledge (2), the empirical nature of scientific knowledge (3), being a product of imagination and creativity (4), being theory-laden (5), the social and cultural structure of science (6), and the difference between observation and inference (7). The first step in most research is to select these aspects according to grade level for a selected sample.

The 90's in NOS studies were about the description of student situations about selected aspects (Abd-El-Khalick & Lederman, 2000b; Lederman, 1992; Lederman et al., 1998; McComas, 1996). Later, studies focusing on the organization of the teaching process to achieve a contemporary understanding of the nature of science came to the fore (Khishfe & Abd-El-Khalick, 2002; Bell et al., 2011; Erdogan & Koseoglu, 2015). Didactically, the teaching of NOS aspects with the explicit-reflective approach and implicit approach (Akerson et al., 2000) and the historical approach are also presented as support (Clough, 2006; Kim & Irving, 2010; Solomon et al., 1992). The explicit-reflective approach argues that NOS aspects should be addressed in a deliberate and planned manner, whereas the implicit approach argues that NOS aspects should be learnt while engaging in science (Abd-El Khalick & Lederman, 2000; Akerson et al., 2000; Demirbas & Balci, 2013). However, the most important difference between the two approaches lies in the way they handle NOS aspects. While the implicit approach considers NOS as an affective learning by-product, the explicit-reflective approach considers NOS as a cognitive learning product similar to other science concepts (Abd-El-Khalick, 2005; Abd-El-Khalick & Lederman, 2000; Khisfe & Abd-El-Khalick, 2002). At the last point, it is stated that teaching with explicit-reflective approach yields effective results (Abd-El-Khalick & Lederman, 2000; Akerson et al., 2000; Flick & Lederman, 2004; Ozcan, 2013). Khisfe and Abd-El-Khalick (2002) also mention that effective results are possible with cognitive teaching.

Regarding students' views on the nature of science, McComas (1996) shared the misconceptions about the nature of science with a 15-item list of 'scientific myths'. It is thought that the role of the preconceptions encountered in or before learning situations in the emergence of these myths is great. Considering the nature of science as a cognitive product (Khisfe & Abd-El-Khalick, 2002), its permanence, and the fact that it requires a deliberate and planned intervention in many studies, it is possible to define these 'scientific myths' as misconceptions. Vosniadou (2008) states that the most important feature that distinguishes misconceptions from other types of errors is that they are permanent and resistant to change.

The Need for Hot Conceptual Change

Science educators have organized various learning situations to eliminate misconceptions in their studies for many years and have emphasized the effectiveness of conceptual change strategies (Dole & Sinatra, 1998; Gregoire, 2003; Kocakülah & Kural, 2010; McLure et al., 2020; Nadelson et al., 2018; Posner et al., 1982; Sinatra, 2005). Conceptual change is considered by Nussbaum and Novick (1982) as a process activated by cognitive and conceptual conflict. Posner et al. (1982) put forward the strategy of conceptual change through a cognitive balancing process that starts with cognitive dissatisfaction with the concept and continues until the search for a comprehensible, plausible, and an efficient new concept (Hewson & Hewson, 1984; Posner et al., 1982). Vosniadou (2008) defined this model as the classical model and stated that the cognitive characteristics of the learner and the conceptual change process were addressed. The classical model's limited focus on students' cognitive processes and the learner-centered approaches in the learning-teaching processes emerging afterwards necessitated including affective and cognitive characteristics in the instruction process. The limited focus of conceptual change on cognitive aspects is characterized as cold conceptual change by Pintrich et al. (1993). The focus of the criticism is that motivational aspects related to the individual are not taken into account. Addressing the effect of motivation and metacognition, Dole and Sinatra (1998) define the process of conceptual change as lukewarm and argue that while dissatisfaction supports motivation, high motivation supports high-level cognition and even metacognition and full conceptual change will be achieved (Özdemir & Kocakülah, 2021). Gregoire (2003) discussed the importance of motivation, self-efficacy, and intuitive-systematic processing processes and clues in the model called warm conceptual change. The warm and hot tendencies of conceptual change mentioned here have led to the idea that there is a multifactorial structure in the process and that each new factor increases the temperature by one level (Kural & Kocakülah, 2016). Considering that there are many factors that directly and indirectly interact with hot conceptual change in learning and teaching processes, a multifactorial conceptual change model has been presented today (Kocakülah, 2024; Nadelson et al., 2018; McLure et al., 2020). As seen, the conceptual change model has also changed in the historical process, as in the approach to NOS teaching.

There are many studies in which NOS aspects are included in the teaching process by combining the explicit-reflective approach with different methods or techniques. In recent years, research-inquiry (Capps & Crawford, 2013; Khisfe & Abd-El-Khalick, 2002; Kinyota, 2020; Ozgelen et al. 2013; Schwartz et al., 2008; Widowati, 2017), argumentation (Acar et al., 2010; Eymur, 2019; Khishfe, 2012; Khishfe, 2014; Khishfe, 2021; Khishfe, 2022; Kutluca & Aydin, 2017; McDonald, 2010), problem-based learning (Akerson et al., 2006; Akerson et al., 2014; Dogan, 2017; Moutinho, et al., 2015; Sousa, 2020) and conceptual change (Abd-El-Khalick & Akerson, 2004; Cho et al., 2011; Clough, 2006; Cil, 2014; Mansour et al., 2016) approaches are frequently encountered in the NOS teaching. Despite these studies, there have been no studies found directly teaching the features related to NOS with the hot conceptual change model in which some affective aspects are also taken into consideration.

Addressing all the above mentioned, this study aims to determine the effectiveness of hot conceptual change strategy based on inquiry-based learning compared with mere inquiry-based learning in changing 7th grade students' NOS views. More specifically, the focus of this study is to evaluate the effect of the application of hot conceptual change to the teaching model on students' understanding of NOS. For this purpose, the following research question was asked: What is the effect of hot conceptual change based teaching on 7th grade students' understanding of NOS.

Material and Methods

Participants

The study was conducted with a total of 24 7th-grade students studying in two different classes in a village school (middle and low socio-economic level) in the South Marmara region of Turkey. From the two classes, the 7/A class was selected as the control group (14 students: 4 girls) while the 7/B class was selected as the experimental group (10 students: 3 girls) by the lottery method. The teaching continued throughout the Light Unit. The 2013 science curriculum was based on the inquiry approach. In both groups, the NOS aspects were integrated with the subject matter in a explicit-reflective approach. In the experimental group, unlike the control group, teaching was planned by including the hot conceptual change model in the process.

Data Collection Tools

The data of the study were obtained by using the Opinions on the Nature of Science Questionnaire (ONSQ) and semi-structured interviews. The ONSQ was administered as a pre-test approximately one month before teaching. Then, semi-structured interviews were conducted with selected students. Thus, the students' pre-instructional views on NOS were obtained. In the lesson after the completion of the instruction, the ONSQ was applied as a posttest. In the following week, semi-structured interviews were conducted again. The posttest data were used to determine how the students' views on NOS changed as a result of the instruction.

ONSQ: A questionnaire with nine open-ended questions developed by Cil (2010) compiled from different studies was used to determine the views on the aspects of the nature of science. The opinions of three faculty members in science education department were obtained about the scale in this form. It was administered to 25 8th-grade students. It was observed that each question generally elicited responses related to the feature to be measured. As such, it was deemed appropriate to administer the ONSQ to the experimental and control groups as pretest and posttest.

Semi-structured interviews: After the administration of the questionnaire, two students from each group were selected voluntarily and interviewed individually. During the interviews, the students were given the questionnaires to examine their own responses and the items in the questionnaire were asked again verbally, thus increasing the validity of the answers given to the questionnaires (Lederman et al., 1998). In addition, the students were asked different questions about science and its characteristics, and their views were tried to be analyzed in depth. The interviews lasted an average of 30 minutes and were then recorded on a computer and transcribed.

Teaching Practices

In the study, NOS aspects were addressed within the 7th-grade light unit. In the learning process, inquiry-based learning (IBL) in the Minister of National Education (2013) Science Curriculum is the basic approach. In the learning process designed for the experimental group, the hot conceptual change model and IBL were integrated. Teaching practices included the concepts of light and NOS aspects (*general view about science, empirical aspect, tentative aspect, imagination and creativity, subjective aspect, social aspect, the difference between observation and inference*). In the present study, the practices related to the 7th-grade learning outcomes were carried out by the researcher, who was a teacher in the Republic of Turkey Ministry of National Education, for 4 hours per week during 7 weeks. In addition, factors and activities for factors were introduced for 4 hours. The practices continued for a total of 28 hours.

While organizing the learning process, the learning cycle was integrated with the inquiry cycle discussed by Pedaste et al. (2015) and the "*Guided Inquiry Process*" described by Kuhlthau et al. (2007). In this way, a learning process in which students will demonstrate their metacognitive skills and motivation is defined. While the instructional strategy IBL, the focus of the curriculum, was arranged, the guided inquiry was brought to the forefront at the 7th-grade level (Ministry of National Education, 2013). For this reason, the guided inquiry was preferred in the study considering the readiness of the students. Khulthau et al. (2007) base the guided inquiry process on theories about the knowledge-seeking process, the third domain, and *know-want-learn* (KWL). The knowledge-seeking process is the provision of all the guidance needed to the learner. The third domain is the creation of a learning process that is life itself by placing the school in the third domain where the pre- and post-learning intersect. KWL is explained as a process in which students take responsibility for all their learning by asking themselves "*What do I know*?", "*What do I want to learn?*", "*What have we learnt?*", "*How do I find out?*", "*How do I share what I have learnt?*" and "*What's next?*" questions in all teaching stages, thus providing support in terms of motivation and metacognition factors (**Figure 1**).

Table 1 shows the IBL process and stages in the experimental and control groups, which were formed by associating the learning process in **Figure 1** with the learning cycle.

Table 1 and **Figure 1** guided the development of lesson plans and student worksheets as well as the IBL process. Experimental and control group lesson plans and student worksheets were prepared for each learning outcome. In the selection of the contents of the control group's lesson plans, the Ministry of National Education textbook was used. In the experimental group, the contents of lesson plans were created by selecting the activities designed by the researchers. Since the development process of the worksheets can be the subject of another research, a detailed explanation is

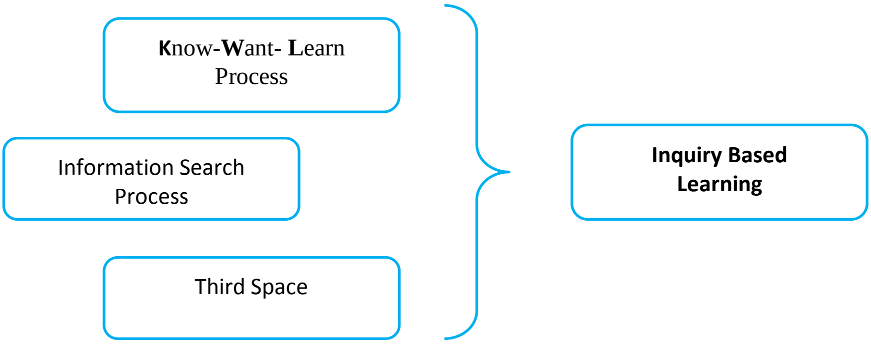

Figure 1. Components of Inquiry-Based Learning.

Table 1. The Process and Stages of IBL in the Experimental and Control Groups.

Main Stages	Sub Stages	Learning Process Question
Preparation	Recalling prior knowledge about the subject	What do I know?
Conceptualization	Questioning and problem-creation	What do I want to know?
Conduct Research	Exploration- experimentation- Interpreting	How to find out and research
Finalization	Sharing Result	What have I learnt? How can I use what I've learnt? What's next?

not given here. However, in terms of validity and reliability, the opinions of 3 experts in the field of science education were taken. In addition, the whole process described here was tested with a pilot study in the same school one year before the actual implementation. All stages and activities were reviewed and deficiencies were eliminated.

The learning process carried out in the experimental group requires the combination of hot conceptual change and IBL. In the hot conceptual change model, the assumption that an individual's affective characteristics affect the conceptual change process together with his/her cognitive characteristics is accepted. In this study, cognitive characteristics were determined as NOS aspects and light concepts, while affective characteristics were determined as motivation towards science lessons, metacognition, and scientific epistemological beliefs. These factors and the hot conceptual change discussed in the current study are shown in **Figure 2**.

As can be seen in **Figure 2**, metacognition, motivation towards science lessons, and scientific epistemological belief factors were integrated

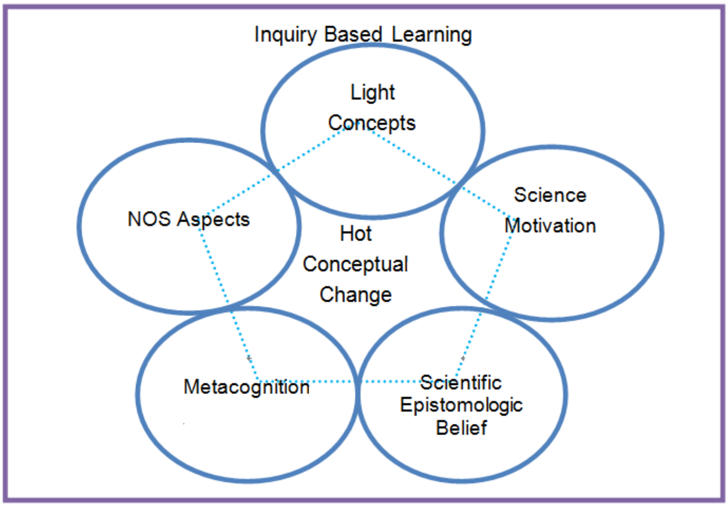

Figure 2. Background of Hot Conceptual Change.

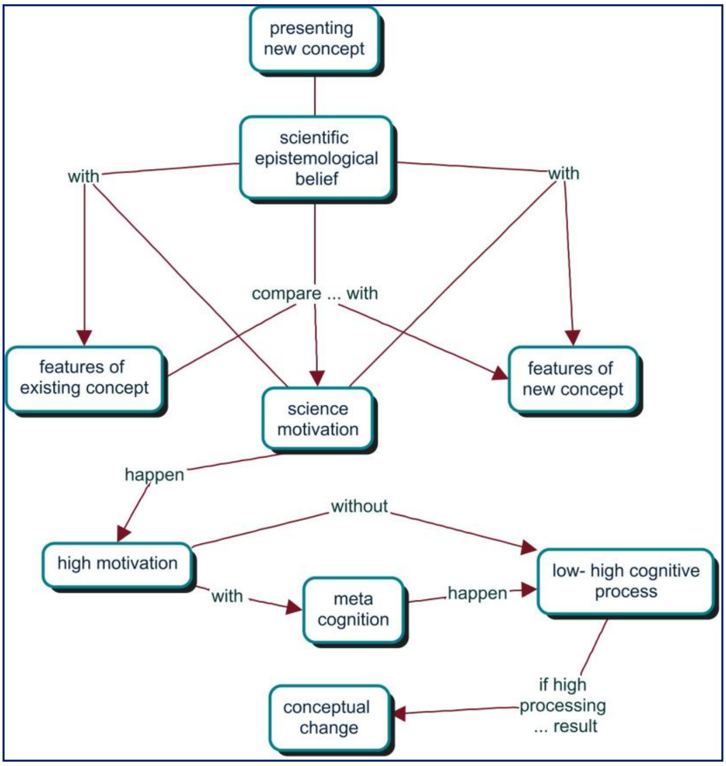

Figure 3. Hot Conceptual Change Process Applied in the Experimental Group.

in accordance with the IBL process to determine a hot path for complete conceptual change. Warm conceptual change was achieved with these factors. Four different activities were designed for motivation and metacognition support. These 5- 10 minutes activities were applied when the students felt that they were having problems, thus students were supported in terms of motivation and metacognition factors. Scientific epistemological beliefs were provided by adding content related to the history of science and the nature of science and thought-provoking questions to the course materials. In this way, students were encouraged to interact to create new ideas. In terms of these factors, students were encouraged to question themselves. For this purpose, they were encouraged to evaluate themselves scientifically. A student list was prepared on the class board. On this board, the class rules created together was listed. At the end of each activity, "the best and the favorites" was determined with the class and symbolic rewards were given. Students' interaction with the factors was ensured through rewards. **Figure 3** shows the flow chart of the hot conceptual change.

The stages in the preparation of lesson plans in the experimental and control groups during the learning process are given in **Table 1** and **Figure 2**. Differently, in the experimental group, planning was made by following the processes in **Figure 3**. During the learning process, the experimental and control group students were divided into subgroups of 3 to 4 students. These groups were tried to be heterogeneous in terms of participation and success. In this situation, the researcher, who is the first author of the article, benefited from his previous experience with the students since he was already the teacher of the course. The students followed the questions and activities in the worksheets given to them during the lessons. Each lesson started with the preliminary knowledge and preparation phase, and it was aimed to understand the learning outcome with the examination of the preliminary knowledge. Students were required to ask themselves the question of "*what do I know?*" This was followed by the conceptualization phase. Here, students started to realize the new outcome. Then, the students were asked the question "*what do I want to know?*" In the experimental group, in addition, "*the comparison of the existing concept and the new concept*" took place at this stage. The next stage was the "*conducting research*" section in both groups. In this section, students designed the learning process through the research process. The teacher presented alternative ideas in addition to the students' own ideas and guided them in the ways they would choose. The main question of the research section was "*How will I learn and research?*" Different from the control group, the students were guided to realize that their existing concepts did not solve the existing problem by comparing the concepts and thus to see the formation of the new concept as a need in the experimental group. In the subgroups that could not achieve this awareness, the researcher provided guidance with additional questions. Finally, in the finalization phase, an evaluation of what has been learnt was made. In addition, a scientific communication process was created, and the student sought answers to the questions "*What have I learnt?*", "*How can I use what I have learnt?*" and "*What is next?*" In the experimental group, at this stage, the results of conceptual change were evaluated, and activities were included for transferring the new concept and monitoring the results. All these processes were presented in separate sections as questions and activity applications in the worksheets of the students, and it was a resource for both the researcher and the student as a lesson plan and course material to follow different parts of the course.

Data Analysis

During the content analysis, students' ONSQ responses related to the aspects of the nature of science were coded as sentences as the unit of analysis. Responses to different questions related to the same aspect were analyzed. In this way, students' ideas about the aspects were categorized as weak (1), variable (2), and high (3). A gain score was calculated between the scores obtained in the pre-test and the scores obtained in the post-test. While calculating the gain score, the normalized gain score (<n>) proposed by Marx and Cumming (2007) was used. In this context, the <n> calculation allows comparison on a student basis and provides a strong statistical basis as the results are high (Setiawan, 2020). Equation 1 was used to find the normalized gain scores.

Equation 1,

$$< \boldsymbol{n} > = \begin{cases} \dfrac{\boldsymbol{POST - PRE}}{\boldsymbol{FULL - PRE}} & ,(\boldsymbol{POST} > \boldsymbol{PRE}) \\ \boldsymbol{0} & ,(\boldsymbol{POST} = \boldsymbol{PRE}) \\ \dfrac{\boldsymbol{POST - PRE}}{\boldsymbol{POST}} & ,(\boldsymbol{POST} < \boldsymbol{PRE}) \end{cases}$$

The coding and scoring process was carried out for the pretest and posttest data. Then, mean <n> was obtained for the groups. To interpret these values, those less than 0.00 were categorized as negative gain; between 0.00 and 0.30 as low gain; between 0.30 and 70 as medium gain; and between 0.70 and 1.00 as high gain (Marx & Cummings, 2007). Comparisons of the groups are presented in the findings section. For the reliability of the scoring, the pretest and posttest ONSQ data were also coded and scored by a faculty member who is an expert in the field of science education. Cohen's kappa analysis was applied for inter-coder agreement

Table 2. Experimental and Control Groups Gain Scores for the Aspect of General Opinion about Science.

Aspect	Group	Pre-test	Post-test	<n>	Gain value
General Opinion about Science	Control Group	1.36	1.64	0.174	Low
	Experimental Group	1.40	2.10	0.438	Middle*

Table 3. Experimental and Control Group Gain Scores for the Empirical Aspect.

Aspect	Group	Pre-test	Post-test	<n>	Gain value
Empirical	Control Group	1.29	1.50	0.125	Low
	Experimental Group	1.20	1.40	0.111	Low

(Kilic, 2015). Cohen's kappa value was found to vary between 0.77 and 0.96 in all aspects and the secondary researcher agreement was interpreted as good and very good ($p < 0.05$). This result is presented as evidence for the scoring reliability of the scale.

Results

The findings obtained by analysing the ONSQ data and the student opinion change schemes are shared respectively. **Table 2** shows the gain scores and values of the experimental and control groups for the aspect of general opinion about science.

According to **Table 2**, it is seen that the experimental and control group students differed in terms of the "*general opinion about science*" aspect and that the control group students had a low level gain and the experimental group students had a medium level gain. When the interviews were analyzed, student K12 said "*science is an invention, discovery and invention*" before the teaching and changed his opinion as "*science is the knowledge found by experiment, observation and research*" after the teaching. Regarding the same subject, D7 first defined science as "*things that make life easier and make the mind work*" and in the last interview, he said, "*It is the correct information that changes and is proven. It can be proved, it can change, it is discovered as a result of experiments*".

Table 3 shows the gain scores of the experimental and control groups for the empirical aspect. When **Table 3** is examined, it is evident that the groups could not differentiate on the "*empirical aspect*" feature of science,

Table 4. Experimental and Control Group Gain Scores for the Tentative Aspect.

Aspect	Group	Pre-test	Post-test	<n>	Gain value
Tentative	Control Group	1.71	2.57	0.667	Middle
	Experimental Group	1.60	2.40	0.571	Middle

both groups remained at low level gains, but the gain value was in favor of the control group.

In the interview records, student D3's statement "*You cannot try something without experiments*" in the pre-interview was changed to "*We cannot try something without experiments. It cannot be done at once, it must be done again and again. Experiments are done to prove, discover and explain*". Furthermore, it is found that the explanation of the K8 that "*experiments are done to discover and investigate" in the pre-interview was changed to "science cannot exist without experiments. I don't know why they are done*". **Table 4** shows the gain scores and values for the tentative aspect as another NOS aspect.

Table 4 shows that the experimental and control group students were at intermediate level of gain and did not differ. On the other hand, it is seen that the normalised gain scores were in favor of the experimental group. When the pre-interview records were analyzed, K12 said "*old knowledge is forgotten and not used. Even the methods here are not used*" and D3 shared the view that "*old knowledge is accepted, but missing knowledge is added*". In the post interviews, K12 used the expression "*old knowledge is forgotten and no longer used*" and D8 used the expression "*old knowledge is forgotten*". On the other hand, in response to the explanation of K12 that "*atoms are first likened to different shapes and then new models are produced according to experiments and their results*", D8 said "*One scientist said that light comes to the eye, another said that it comes to the object. Another one found that we see with the light reflected from the object*" and supported his sufficient opinion about the tentative aspect with an example.
The next findings regarding the gain scores and values of the experimental and control group students related to imagination and creativity are shown in **Table 5**.

Regarding the "*imagination and creativity aspect*", it was found that the experimental and control group students were in the middle level of gain, that is, they could not differentiate (**Table 5**). On the other hand, it is seen that there is a differentiation in favor of the experimental group in the normalized gain scores. In the pre-interviews, it was determined that K8 shared the explanation of "*imagination is what you think*" and D3 shared the explanation of "*creativity is design*". In the final interviews, it was observed

Table 5. Experimental and Control Group Gain Scores for the Imagination and Creativity Aspect.

Aspect	Group	Pre-test	Post-test	<n>	Gain value
Imagination and Creativity	Control Group	2.21	2.57	0.455	Middle
	Experimental Group	1.70	2.40	0.538	Middle

Table 6. Experimental and Control Group Gain Scores for the Subjective Aspect.

Aspect	Group	Pre-test	Post-test	<n>	Gain value
Subjective	Control Group	1.93	2.50	0.533	Middle
	Experimental Group	1.60	2.70	0.738	High*

Table 7. Experimental and Control Group Gain Scores for the Social Aspect.

Aspect	Group	Pre-test	Post- test	<n>	Gain value
Social	Control Group	2.14	2.29	0.167	Low
	Experimental Group	1.80	2.80	0.833	High*

that K8 stated "*imagination is to dream*", while D3 stated "*imagination is the beginning of the next invention*".

Table 6 shows the findings including the gain scores and values of the groups regarding the 'subjective element'. When **Table 6** is analyzed, it is observed that the experimental group obtained high level gain and the control group obtained medium level gain. There is a difference in favor of the experimental group in terms of the subjective aspect. In the pre-interview, it was found that the students in the experimental and control groups answered the question about the reason why scientists' explanations about the same subject were different with the common explanation "because their feelings and thoughts were different". In the final interview, it was observed that student K8 said "*they do not use their emotions, there is no need because they already find out through experiments and observations*", whereas D7 said "yes, they do, but emotions, thoughts and ideas can change according to everyone". **Table 7** shows the gain scores and values of the experimental and control group students about the social aspect of the NOS.

When the "social aspect" data is examined, results in favor of the experimental group are noticed. It was found that the experimental group students had high gains while the control group students had low gains

Table 8. Experimental and Control Group Gain Scores for the Difference between Observation and Inference.

Aspect	Group	Pre-test	Post- test	<n>	Gain value
Difference between Observation and Inference	Control Group	1.79	2.00	0.176	Low
	Experimental Group	1.80	2.70	0.750	High*

(**Table 7**). When the interview records were analyzed, it was found that student K8 stated "*it does not affect the society, but it affects the structure of the society: science is affected by the society, it takes the society's opinion*" and D3 also stated "*it does not affect the society, it affects (later), I do not know*" in the pre-interviews. In the final interviews, student K8 stated that "*science affects the societies, the traditions of the society they live in are important. It meets the needs of the society they live in, after all, the society uses what is found*"; D3 said, "*No, it does not affect. It meets the needs of the society they live in. Society cannot exist without science; science cannot exist without society*".

Table 8 presents the results of the analyses of the gain scores and values of the students in the experimental and control groups on the last aspect, the difference between observation and inference.

Differences were found in the gain scores and values of the experimental and control groups regarding the difference between observation and inference in favor of the experimental group (**Table 8**). Among the students' opinions obtained from the interviews related to this aspect are as follows: In the pre-interview, student K12 said "*Observation is to analyze something. Inference is to deduce the result of a process*." For D7, "*observation: I have no idea*" and did not mention inference. In the post interviews, the student in the control group stated that he had no idea about observation and inference and provided the explanation that "*weather forecasts are made from satellites outside the world*". In the post interview of the experimental group, D7 said "*Observation is looking at something. It is to see how something happens in experiments. It is to take note of what is seen. Inference is the interpretation made as a result of observation*".

Discussion

In this study, the effect of the instructional model developed on the basis of hot conceptual change on middle school 7th-grade students' understanding of NOS aspects was investigated. The analyses showed that the experimental and control group students had largely weak views in terms of all NOS aspects before the instruction. Considering that the students participating in this study have been taking science courses since the 3rd-grade, the results obtained can be interpreted as that the current science program does not contribute to the students' adequate level of NOS understanding. Similar to the results of this study, many studies in the literature reveal that although students have received a formal science education, their understanding of NOS is not at the desired level too (Bell et al., 2011; Kang et al., 2005; Khishfe, 2020; Parker et al., 2008; Peters-Burton et al., 2022).

The results obtained after the instruction show that the gain scores of the students in both groups are in the direction of positive gains ranging between low and high levels. Although science-related activities produce effective results in the development of NOS, they do not provide the development of a comprehensive understanding of NOS (Alisir & Irez, 2020; Flick & Lederman, 2004; Khisfhe, 2022). However, it is thought that the reason for the small gain differences in the present study is that the practices in both groups were directly based on the philosophy of explicit-reflective approach. In support of this idea, Ozer et al. (2021) state that more activities do not mean more development of accurate NOS understanding.

It was found that the gain scores in the aspects of general view about science, social aspect, and subjective aspect, the difference between observation and inference in the experimental group were higher than the gain scores in the control group, which may be due to the hot conceptual change. Dole and Sinatra (1998) defined cognitive conflict and motivation for conceptual change and the motivation processes that lead to the activation of metacognition. In the present study, the use of quotations from the history of science and interesting activities may explain the results in favor of the experimental group. It is also seen in the literature that historical scientific events as a complement to science-related activities are an effective way to develop students' understanding of the nature of science (Abd-El-Khalick, 2005; Alisir & Irez, 2020; Khishfe, 2022; Solomon et al., 1992). On the other hand, no significant difference was found between pre-service teachers who received a short education on the history of science and philosophy of science and those who did not receive this education in terms of NOS views (Erdas Kartal et al., 2018). Based on all these results, it is thought that the changes in some NOS views in favor of the experimental group in the current study are the product of hot conceptual change. On the other hand, it is not possible to know how much the effect of the history of science stories and activities used to support the teaching process in the study. Investigation of such an effect can be carried out as the subject of another study.

Although both groups obtained positive results in terms of NOS aspects, it was found that the control and experimental groups did not differ in terms of empirical aspect, tentative aspect, imagination, and creativity. After the application, it was concluded that weak opinions decreased in both groups, but there was no differentiation in gain values although variable and sufficient opinions increased. The first aspect related to this situation is the empirical nature of science where low gains are seen. When the studies focusing on the teaching of NOS aspects are examined, it is seen in various studies that there are weak opinions about the empirical aspect before the application (Bakirci et al., 2017; Bell et al., 2016; Brunner & Abd-El-Khalick, 2020; Schellinger et al., 2019).

It is stated that research-based activities contribute to the change of students' views on the nature of science (Akerson et al., 2014; Schellinger et al., 2019). Similarly, studies that obtained significant results related to the experimental aspect with the conceptual change process were also found (Bakirci et al., 2017; Bell et al., 2016; Clough, 2006). In addition, it was observed in the interviews that the students maintained the view that "*there is no research without experimentation*". It is thought that this finding may have resulted from the association of experiments with science, which is very appropriate to the nature of science education (Irez, 2015; Khishfe, 2022; McComas, 2004). It is also thought that the guided inquiry planned in the research phase of the course in this study may have revealed the belief that "*experiment is a must*" (Akerson et al., 2014). This situation arising from the nature of teaching can be presented as a limitation. However, considering that the foundation of students' naive ideas is shaped from an early age, it can be argued that the "*crazy scientist figure doing explosive experiments*" that students may encounter in the media or in various books may have contributed to the establishment of the view that "*science is experimentation*" as a fundamental and indestructible misconception. However, it may be suggested to plan different studies to reveal how this view is so ingrained in the minds of the students.

It was observed that another aspect in which the experimental and control groups reached medium level gains before the application and did not differentiate as a result of the application was the tentative nature of science. Variable opinions were found to be intense in both groups and similarly, weak and variable opinions were found in different studies in the field before the implementation (Bakirci et al., 2017; Bell et al., 2016; Clough, 2006; Schellinger et al., 2019). After instruction, the groups gained medium level gains related to the tentative aspect. In addition, hot conceptual change did not cause differentiation between the groups. Although significant results were obtained in different age groups with the applications carried out in some studies on the tentative aspect (Bell et al., 2016; Clough, 2006; Khishfe, 2022; Schellinger, et al., 2019), it was observed that the pedagogy related to conceptual change also revealed positive results (Bakirci et al., 2017; Cil, 2014). However, no study has been encountered regarding the hot conceptual change and the tentative aspect. It is thought that the activities in the worksheets prepared for the hot conceptual change process in the current study may not have been followed by the students or may have been boring. In addition, the fact that students do not read scientific content in daily life is another problem (Bakirci, et al., 2017). As a suggestion here, the motivation process can be contributed to by creating a conflict process with cartoons involving more pictures or with short documentaries on the history of science. Considering these, experimental research can be conducted to determine which one affects the hot conceptual change process more.

Another result is that the gain scores related to the aspects of imagination and creativity constitute medium level gains for the experimental and control groups. Prior studies show similarities in the distribution of opinions before the instruction in different age groups (Erdas Kartal et al., 2018; Bell et al., 2016; Khishfe, 2022). Despite the decrease in weak opinions after the instruction, the rate of adequate opinions in the experimental group was 40% and 64% in the control group. It has been observed that there are studies that have achieved positive results in the opinions of the sample with different applications (Bell, et al., 2016; Erdas Kartal et al., 2018; Khishfe, 2022). However, positive results of the applications related to conceptual change on student development in the aspect of imagination and creativity are also found (Bakirci et al., 2017; Cil, 2014). On the other hand, in Ozer et al.'s (2021) study, while there was no significant difference in the results of 5th- and 6th-grade students in the context of age groups, a significant difference was found in 7th-grade students. As a result of this study, it was explained that there is a misconception in Turkey because creativity and imagination are handled in the context of art and artists. It is necessary to evaluate the situation in the current study differently. Although there was an improvement in the groups towards creativity and imagination aspect, there was no differentiation in the experimental group. However, it is thought that this situation may have occurred as a result of a common effect of age, aspect, and application due to the disadvantages of the settlement where the sample is located. The reasons for the emergence of this result can be suggested as the subject of another study.

Accordingly, it was concluded that the hot conceptual change model applied in the experimental group was effective on some NOS aspects. Bakirci et al. (2017) examined the effects of the *Common Knowledge Constructs Model* (CKCM) and the 5E model on 6th-grade students' views on the nature of science. In the study, results were obtained in favor of the experimental group in terms of the development in NOS views. In the literature, there are other studies in which positive developments have been observed in the groups in which conceptual change pedagogy for NOS was applied (Cil, 2010; Cil & Cepni, 2016). In another similar study in which the sample was selected as pre-service teachers, Abd-El Khalick and Akerson

(2004) determined that the views of pre-service teachers who initially had weak views improved with the explicit-reflective NOS approach under conceptual change-based learning conditions. These studies in the literature provide evidence to support the results obtained in this study.

It was concluded that the explicit-reflective approach based guided IBL process applied in the control and experimental groups was effective in developing positive gains related to NOS aspects compared to the pre-instruction. When the literature is examined, it is stated in many studies that successful results can be obtained by addressing NOS aspects as an explicit, reflective, and cognitive product (Lederman et al., 1998; Schwartz et al., 2004; Teig et al., 2019). Sagır and Kilic (2013) explain that scientific discussions in which communication and discussion are at the forefront are more effective than the traditional method. Here, the Guided IBL process in the basic framework of teaching practices is considered as a process that includes all the skills mentioned (Constantinou et al., 2018). In this respect, it is thought that the Guided IBL process may have contributed to students' understanding of the NOS.

The qualitative findings obtained from this study shows that metacognition, motivation towards science lessons, and scientific epistemological belief factors were effective in supporting the hot conceptual change process. In addition, these findings could explain the results obtained in favor of the experimental group in terms of some of the NOS aspects in the experimental and control groups. It should be noted that the student group in which the research was conducted was located in a rural area and had families at low socio-economic level posed a significant problem for the researchers during the teaching process. During this research, it was observed that students' transfer to school by shuttle sometimes caused them to be late, and this situation caused some lessons to be prolonged and as a result, their motivation decreased. Therefore, it is recommended that such factors should be taken into consideration in future similar studies.

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