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A Look into Students' Retention of Acquired Nature of Science Understandings

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A Look into Students' Retention of Acquired Nature of Science Understandings

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Having the learning and retention of science content and skills as a goal of scientific literacy, it is significant to study the issue of retention as it relates to teaching and learning about nature of science (NOS). Then, the purpose of this study was to investigate the development of NOS understandings of students, and the retention of these understandings four months after being acquired through explicit reflective instruction in relation to two contexts. Participants were 24 tenth-grade students at a private high school in a city in the Middle East. Explicit NOS instruction was addressed within a six-week unit about genetic engineering. Three NOS aspects were integrated and dispersed across the unit. A questionnaire, together with semi-structured interviews, was administered as pre-, post-, and delayed post-test to assess the retention of participants' NOS understandings. The questionnaire had two open-ended scenarios addressing controversial socioscientific issues about genetically modified food and water fluoridation. Results showed that most students improved their naïve understandings of NOS in relation to the two contexts following the six-week unit with the explicit NOS instruction. However, these newly acquired NOS understandings were not retained by all students four months after instruction. Many of the students reverted back to their earlier naïve understandings. Conclusions about the factors facilitating the process of retention as the orientation to meaningful learning and the prolonged exposure to the domain were discussed in relation to practical implications in the classroom.

Keywords: *Nature of science; Retention; Socioscientific issues; Scientific literacy*

Introduction

The vision of Project 2061 for schooling in the twenty-first century focuses on the learning and retention of science content and skills, which is a goal of scientific literacy

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(American Association for the Advancement of science [AAAS], 1989). Toward achieving that, the new curriculum advocated by the new reforms has far fewer topics than the traditional curriculum so that students can concentrate on learning well the ideas and skills and retain them for the future to possibly use them in their everyday lives. Equally, the importance of the retention of information taught in schools has been seriously highlighted by Semb and Ellis (1994):

> The very existence of school rests on the assumption that people learn something of what is taught and later remember some part of it. This knowledge is often a prerequisite for knowing when and how to perform jobs and tasks in the real world, for making educated choices as consumers and citizens, or for taking advanced schooling. (p. 253)

Over the years, it has been found that students seem to have difficulty with the lack of retention of the concepts (Chow, Kelly, Woodford, & Maes, 2011). Hence, students' inability to retain information for a long period of time after initial instruction is an important focus in education. The common belief is that much of the information acquired at school gets lost, which is a serious problem for schooling (Semb & Ellis, 1994).

With the many studies by educational psychologists focusing on different aspects of knowledge retention, retention is treated as one phase of a dynamic model of the general learning process (Kohen & Kipps, 1979). According to these authors, previous research has shown that once the concepts are learned, they are not immediately or entirely forgotten. Additionally, the level of retention diminishes with the course of time. The longer the time interval, the intervention will have less effect on the learners' current understandings. However, Semb and Ellis (1994) claim that the loss of the information is not as critical or significant as is believed. And beyond doubt, that claim needs further study and research.

The retention interval refers to the time between the test of original learning, which follows classroom instruction and the retention test. Many researchers bound the short-term retention interval to single sessions (e.g. Gagne, 1978), days, or weeks (Bahrick, 1979). On the other hand, other researchers bound the long-term retention interval to a wider time scale that extends to few months (e.g. Brosvic, Epstein, Dihoff, & Cook, 2006; Upadhyay & DeFranco, 2008), a single year (e.g. Matić & Dahl, 2014; Semb, Ellis, & Araujo, 1993), or even few years (e.g. Conway, Cohen, & Stanhope, 1991; Eikenberry, 1923; Engelbrecht, Harding, & Du Preez, 2014; Powers, 1925). Xiong and Beck (2014) explored whether a different retention interval (1, 4, 7, and 14 days) would affect students' retention of mathematics skills. Results showed that students in longer retention interval had lower retention performance compared to those in shorter retention interval, but none of the differences were particularly large. In this study, the focus was on the issue of long-term retention that takes place over few months. The rationale for the four months chosen as the length of time for retention was based on having to start with a 'primary' or 'initial' stage to explore the retention in order to gain some understanding about the issue of retention before we explore the retention over longer period of time. Plus, longer interval knowledge retention is harder to assess (Wang & Heffernan, 2014).

Empirical Studies on Retention

Generally speaking, there have been limited research studies that investigated the retention of learners when utilizing different instructional methods in different domains. For the non-science domains, it was found that (a) students retained the concepts better in geometry when the discovery method was used for instruction (Scott, 1970); (b) taking prior tests (particularly a short answer test) produced significantly better retention of the art history material for undergraduate students than studying a lecture summary or taking a multiple choice test (Butler & Roediger, 2007); (c) fourth- and fifth-grade students retained better on mathematics fact retention and generalization when the computer-based practice was used for instruction (Kanive, Nelson, Burns, & Ysseldyke, 2014); and (d) the retention of former university students in cognitive psychology declined over the first few years and then stabilized (Conway et al., 1991). With respect to empirical studies addressing the retention of science concepts, all three reviewed studies (Ozden & Gultekin, 2008; Sarikaya, Guven, Goksu, & Aka, 2010; Upadhyay & DeFranco, 2008) pointed to the finding that it is possible to improve the retention of knowledge for learners at different levels using non-traditional approaches (connected, brain-based, constructivitist). Yet, the little research in education that systematically targets the retention of what is taught in schools makes it crucial to investigate whether students remember or retain the knowledge learned in a school setting and how much they retain.

Nature of Science

An understanding of the nature of science (NOS) has long been emphasized as a vital component of scientific literacy (AAAS, 1989, 1993; Council of Ministers of Education Canada [CMEC] Pan-Canadian Science Project, 1997; National Research Council [NRC], 1996). Students need to understand the values and beliefs inherent to the development of scientific knowledge (Lederman, 1992).

Driver, Leach, Millar, and Scott (1996) summarized five potential arguments for the inclusion of NOS in science teaching. NOS helps students to (a) understand the process of science, (b) participate in debates and decision-making in relation to socioscientific issues, (c) develop an appreciation of science as a fundamental block of contemporary culture, (d) develop commitments to the norms of the scientific community, and (e) learn the science content.

In spite of the repeated emphasis in major reform science education movements and all the arguments about its inclusion in the science curricula, no agreement has been reached on a universal definition of NOS. However, a certain extent of convergence about NOS has been recognized among science educators. In view of that, NOS is commonly defined as the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development (Lederman, 1992). Built on that, there is a shared judgment about some general characteristics of the scientific enterprise (Lederman, 2007) that are generally considered as being related and relevant to K-12 students' everyday lives (Abd-El-Khalick, Bell, &

Lederman, 1998) and those aspects have also been advanced in reform documents in science education (AAAS, 1989, 1993; NRC, 1996). These aspects entail understanding that scientific knowledge is tentative (subject to change); empirical (based on and/or derived from observations of the natural world); subjective (influenced by scientists' background, experiences, and biases); imaginative and creative (involves the invention of explanations); and socially and culturally embedded. Additional aspects are the distinctions between observations and inferences, and the relationships between scientific theories and laws.

Attempts to Improve NOS Understandings

Many attempts have been invested toward helping students to develop informed views of NOS (VNOS). Along these lines, there has been support for success in promoting NOS views when using an explicit approach to help learners develop more informed understandings of NOS aspects (e.g. Abd-El-Khalick, 2001; Abd-El-Khalick & Lederman, 2000; Akerson, Abd-El-Khalick, & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002; Khishfe & Lederman, 2006; Schwartz & Lederman, 2002). An explicit approach to teach about NOS endows learners with opportunities to react and reflect on NOS aspects in relation to the lessons and/or activities under study (Abd-El-Khalick & Lederman, 2000).

The success of an explicit approach on students' understandings of NOS has been explored in several contexts: (a) historical (e.g. Klopfer & Cooley, 1963; Leach, Hind, & Ryder, 2003; Solomon, Duveen, Scott, & McCarthy, 1992), (b) inquiry (e.g. Carey, Evans, Honda, Jay, & Unger, 1989; Khishfe & Abd-El-Khalick, 2002; Khishfe, 2008; Liu & Lederman, 2002), and (c) socioscientific issues (e.g. Khishfe & Lederman, 2006; Walker & Zeidler, 2007), which are science-related social open-ended dilemmas (Sadler & Zeidler, 2005). However, it is not clear whether students retain these acquired understandings beyond the unit or course addressed in the research study. Although all the above studies reported relative success in helping in enhancing students' understandings of NOS, none of them investigated whether these acquired understandings are retained. After the end of the unit or course, will students continue to hold those acquired understandings? Will some students retain those views and other students revert? If so, why?

To the author's knowledge, only one study (Akerson, Morrison, & Roth McDuffie, 2006) has addressed this issue of retention in relation to NOS understandings with preservice teachers. In their study, Akerson et al. (2006) investigated the retention of preservice elementary teachers' understandings of NOS after they explicitly learned about NOS during a science methods course. Results showed that most preservice teachers improved their naïve understandings of NOS after one semester of instruction in the science methods course. However, five months after instruction, these newly acquired understandings were not retained by all preservice teachers, where several of the teachers reverted back to their earlier naïve understandings. Nevertheless, there have been no studies that have explored this issue at the student level. Such is the main focus of this study, which seeks to add to the knowledge base by exploring these issues.

Context of NOS Instruction

In the present study, we chose socioscientific issues as the context for NOS instruction. Socioscientific issues have been advocated as a natural and inherent context for discussing NOS ideas (Khishfe & Lederman, 2006; Matkins & Bell, 2007; Walker & Zeidler, 2007) as they present 'science in the making' and bring students into direct contact with the characteristics that compromise scientific knowledge. As noted earlier, the relative success of teaching NOS in the context of socioscientific issues has been documented in recent work (Khishfe & Lederman, 2006; Matkins & Bell, 2007; McDonald, 2010) in relation to improving learners' understandings of NOS.

It is also important to note that the context of the socioscientific issue itself has an influence on students' understandings of NOS. Khishfe (2012a) claimed that the familiarity of the socioscientific issue influenced how students connected to the issue, especially if it is more related to their everyday lives. Previous studies have also shown that participants elucidated more informed understandings of NOS (Khishfe & Abd-El-Khalick, 2002) when the issue was more familiar to participants and when they had more prior science content knowledge about it (Abd-El-Khalick, 2001). Lewis and Leach (2006) actually found that students were influenced by whether the targeted issues were outside of their experience or had little relevance to their immediate lives. As such, the question of the context of the socioscientific issue is worth addressing in the present study and thus explore whether the development and retention of NOS understandings would be similar for different controversial socioscientific issues.

As such, three contexts were tackled in the present study: (a) the learning context of the treatment and that represented the context in which the learning of NOS took place (genetic engineering), (b) the first application context (the socioscientific issue about genetically modified food) and that is depicted as being related to the science content about genetic engineering, and (c) the second application context (the socioscientific issue about water fluoridation) and that is characterized as being unrelated to the learning context.

Purpose

With all these issues around the retention of knowledge, it is very important to explore how that is manifested in relation to students' acquired NOS understandings. As such, the purpose of the present study was to investigate the development of students' NOS understandings and the retention of their acquired understandings across time (four-month period) following explicit NOS instruction. The questions that guided the present study were:

(1) How do the NOS understandings of tenth graders change as a result of explicit NOS instruction in relation to the two contexts about genetically modified food and water fluoridation?
(2) Are tenth graders able to retain their newly acquired understandings of NOS over a four-month period in relation to the two contexts about genetically modified food and water fluoridation?

(3) How does the retention of the acquired NOS understandings over a four-month period differ between the two contexts about genetically modified food and water fluoridation?

It is important to note that this study has been based on a previous investigation (Khishfe, 2012b) that explored whether students transfer their newly acquired NOS understandings, which were explicitly taught in relation to one socioscientific context, into similar socioscientific contexts. That previous study addressed students' learning of three NOS aspects (subjective, empirical, and tentative) and the transfer of their acquired understandings following a six-week unit about genetic engineering with explicit NOS instruction. Khishfe (2012b) reported on the results of the pre- and post-instruction results for two groups related to the two contexts to answer the research questions about learning and transfer. However, the present study primarily involves and focuses on the results of the development and retention of one group and reports on the delayed post-test relative to the pre- and post-test administration for the two contexts in order to address the questions about the development and retention of students' acquired NOS understandings over a four-month period following the six-week unit about genetic engineering with explicit NOS instruction.

Method

Participants

Participants in the present study were 24 tenth-grade students (13 female and 11 male) at a private school in a city in the Middle East. The students at the school were Arabs who came from families of middle socioeconomic status with different religious sects. The average age of participants was 15.6 years. Students were taught by the teacher who was purposefully selected based on evidence of improvement in his NOS understandings and the ability to apply these informed NOS understandings into his classroom practice. The evidence of his NOS understandings was built on his responses to an open-ended questionnaire targeting NOS issues and the evidence for his practice was based on the review of some of his classroom lessons that targeted explicit instruction of NOS. The teacher also showed a strong intention to integrate NOS and teach it explicitly within the regular science content. The teacher had a Bachelor of Science (BS) in Biology and was working on his Masters in Science Education at the time of the study. The teacher had five years of teaching experience at the school, which used English as the language of instruction for science.

Procedure

Prior to the study, all participants were administered an open-ended questionnaire (Appendix) three times during the study: (a) at the beginning of the study, (b) at the end of the treatment unit, and (c) four months after the end of the treatment. A sample of participants was selected for individual semi-structured interviews following each administration of the open-ended questionnaire.

Treatment. The treatment spanned six weeks and involved a unit about genetic engineering. Explicit NOS instruction was addressed in the unit and the discussions focused on only three NOS aspects (empirical, tentative, and subjective). It is believed that these three NOS aspects are directly connected with the discussions about socio-scientific issues (Khishfe, 2012b; Zeidler, Walker, Ackett, & Simmons, 2002).

The topics in the unit included cloning, stem cell research, DNA profiling, genetic engineering in the field of agriculture, genetic engineering in the field of animal farming, and genetic engineering in the field of medicine. Each of these topics was experienced in more than one session, which lasted 100 minutes. Participants worked in small groups consisting of about four students. Six tasks and/or cases were given for each group with its members to analyze and research. The group members played different roles (e.g. the scientist, the doctor, the religious person, and the civil rights defender) and they had to defend their positions for each of the cases that were discussed. Students were asked to research the topic, and then the discussions took place during the sessions.

Each of these topics was targeted in a similar format, where the teacher would ask about the general definition and the purposes of the genetic engineering procedure to be targeted in the session. The participants who were assigned the role of scientists would present the steps and procedure while highlighting the advantages and the disadvantages. Then the floor was given for other students with the different roles as the doctors, the ethicists, the environmentalists, and the religious advocates to discuss the issues from their own perspectives.

For the explicit NOS instruction, participants engaged in discussions and reflections of the three emphasized NOS aspects (empirical, tentative, and subjective) following the presentation and discussions given by the different group members. These explicit reflective discussions about the NOS aspects were incorporated within the science lessons throughout the unit and they were given in the distributed NOS model (Khishfe & Lederman, 2006, 2007). In that way, participants were provided with several reflective experiences to reflect on NOS aspects as it relates to the various lessons about genetic engineering. By dispersing NOS instruction across the unit, that would enable students to experience multiple exposures to NOS to be able to comprehend the NOS themes in different contexts.

Classroom discussions about these emphasized NOS aspects, aided by written questions, were integrated within every other session throughout the unit. For example, the teacher integrated explicit and reflective discussions about the empirical aspect of NOS by utilizing guiding questions as, 'What did scientists base their conclusions on?' Emphasis by the teacher included focus on observations, experimental data, and prior knowledge. For discussions on the subjective aspect of NOS, the teacher discussed issues related to discrepancy in scientists' interpretations and conclusions based on different perspectives, beliefs, experiences, background knowledge, and religion. Discussions revolved around the manners in which scientists might be influenced by such beliefs in their interpretations and conclusions. As for targeting the tentative aspect of NOS, the teacher raised questions as, 'Do you think these scientists would change their knowledge or conclusions later on, and why or why not?' The points of focus rotated around the notion that scientists reach the 'best' existing conclusions based on the available evidence, which might change in the future. The ideas about science as the 'absolute truth' against the change in scientific knowledge were brought up at various points throughout the unit.

Data Sources and Collection

To assess the development of participants' NOS understandings and their ability to retain their NOS understandings, an open-ended questionnaire (Appendix), followed by individual semi-structured interviews to a sample of the participants, was administered three times in the study. Individual semi-structured interviews followed the administration of the questionnaires.

It is important to note that we have not used any of the already published NOS questionnaires in the present study as none of them address the context of socioscientific issues. Yet, the items targeting the three emphasized NOS aspects in the present study are aligned and comparable with items that target the same NOS aspects used in the VNOS instrument (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). The questionnaire used in the present study had two open-ended scenarios that address the two controversial socioscientific issues about genetically modified food and water fluoridation. Following the scenarios were questions that assessed participants' views about the tentative, empirical, and subjective aspects of NOS. The two scenarios have been used in the previous study (Khishfe, 2012b), on which the study is based. The content validity of the scenarios was established by the input of experts (two science educators, three biologists, two ethics professors, and three high school biology teachers) and that required some revisions based on the experts' feedback. Additionally, pilot testing of the scenarios was carried out with 38 grade 10 participants in 2 schools that were in the same city but did not participate in the study. Following the administration of the scenarios, some of these participants were also interviewed to get an in-depth understanding of their interpretations of the different items.

A random sample of 10 participants was selected for individual interviews to further establish the face validity of the participants' responses to the open-ended questionnaire by ensuring the researcher's interpretation matched those of the participants. Five participants were selected for individual interviews following the administration of the pre-, post-, and delayed post-questionnaire. In this way, the same five students were interviewed three times during the study. The same students were selected for interviews to gain a deeper comprehension and insight about the development of students' understandings of the emphasized NOS aspects. Each interview lasted 25–45 minutes. During the interviews, the participants were given their questionnaires and they were asked to explicate their responses to the two different scenarios and give more examples. The interviews were audiotaped and then later transcribed verbatim.

Data Analysis

All the data were analyzed by the author. First, the analysis of the delayed post-instruction interview transcripts and the corresponding questionnaires was done separately to generate profiles of participants' views of the emphasized three NOS aspects. The comparison of the two independently generated profiles showed that the two profiles were comparable for each interviewed participant.

Yet again, the questionnaire for each participant was analyzed and participants' responses were categorized into naïve, informed, or intermediary for each of the three NOS aspects. The author and another science education researcher categorized participants' understandings. The science education researcher was blinded to whether the questionnaires belonged to the pre-, post-instruction, or delayed post-instruction data. The agreement between the two researchers on the categories was more than 85%. Multiple consultations of the data were conducted until consensus between the two researchers was reached across all emphasized NOS aspects for the categorization of participants' responses.

Each participant's understanding of the emphasized NOS aspects was categorized by the two researchers into naïve, intermediary, or informed. Table 1 provides examples of the categorization of student responses in relation to the three NOS aspects at three different levels in response to the first scenario about genetically modified food. These examples represent verbatim quotes of participants' responses.

A participant's understanding of a particular NOS aspect was categorized as 'naïve' when the response about the NOS aspect was not in line with the acceptable NOS views embraced in the science education reform documents (AAAS, 1989, 1993; NRC, 1996). For example, one of the participants explained that 'different scientists would reach the same conclusions about the effects of water fluoridation or else they might be looking at different data'. This understanding was categorized as naïve for the subjective aspect of NOS.

An understanding of a participant about a NOS aspect was categorized as 'intermediary', particularly as the 'multiple' form that occurred in this study, when there were co-existing fragmented and contradictory views (Khishfe, 2008). As an example, one of the participants exhibited a naïve and an informed understanding that contradicted each other, so the participant's understanding was categorized as intermediary. When responding to the same item that addresses the subjective aspect of NOS, this participant elucidated that different scientists can reach different conclusions because 'they have different perspectives on things'. However, he also stated that 'different scientists would reach different conclusions because they were looking at different data'.

An understanding of a NOS aspect was considered as 'informed' when it was consistent with acceptable VNOS. For example, the response of this participant was categorized as informed for the subjective aspect of NOS. She explicated that scientists

Table 1. Categorization of responses to scenario 1 about water fluoridation related to NOS understandings

NOS aspect	Naïve views	Intermediary views	Informed views
Subjective	Different scientists would reach the same conclusions about the effects of water fluoridation or else they might be looking at different data	Scientists have different perspectives on the issue [of water fluoridation] … but [scientists] might have looked at something in the wrong way so they got different conclusions	[Scientists might reach different conclusions when looking at the same data] because they can be influenced by their backgrounds, what they already know about adding fluoride to water, what they had experienced before, and how much ethical beliefs they have
Tentative	What we have about water fluoridation, this knowledge will not change. It has already been established by scientists	The knowledge [about water fluoridation] might change in the future, if we have new studies but the knowledge should not change because it is proven already	Yes, the knowledge about water fluoridation might change, it will because we will know more about effects of water fluoridation, well with the newly updated researches concerning the effects of water fluoridation
Empirical	I am satisfied with the water fluoridation situation and how it affects people. Everyone else should also be okay about it because this has been approved by FDA	I believe water fluoridation might change in the future because of new studies that can provide new evidence so it will change the scientific knowledge but then I think that scientific knowledge cannot change … this is hardcore science so it should not change	This knowledge about effects of water fluoridation might change if the group against water fluoridation can actually back up their debates with actual evidence, so there need to be more studies and research about this

might reach different conclusions when looking at the same data because ‘they can be influenced by their backgrounds, what they already know about adding fluoride to water, what they had experienced before, and how much ethical beliefs they have’.

To address the first question about the change in the NOS understandings of tenth graders as a result of explicit NOS instruction in the two contexts, the development in participants’ understandings of NOS was compared between the pre- and post-questionnaire in relation to each of the three emphasized NOS aspects for the two scenarios (genetically modified food and water fluoridation). With regard to the second question about whether participants were able to retain their newly acquired understandings of NOS across the four-month period in relation to the two contexts, the development in participants’ understandings of NOS was compared between the post- and delayed post-questionnaire in relation to each of the three emphasized NOS aspects for the two scenarios. As for the third question about comparing the retention between the two contexts, the developments in participants' understandings were compared between the two scenarios.

Results

The results trace the development, the retention, and the regression of participants' understandings for each NOS aspect in relation to the first scenario (genetically modified food) and the second scenario (water fluoridation). Generally, there were considerable improvements in participants' understandings of the three NOS aspects in relation to both contexts. Moreover, the delayed post-instruction data showed some retention in participants' informed understandings of the subjective, tentative, and empirical aspects relating to the two contexts. Table 2 provides a summary of the results showing the percentage of participants with informed, intermediary, and naïve understandings of the emphasized NOS aspects for the pre-, post-, and delayed post-instruction data for the two scenarios. Tables 3 and 4 present student-by-student data showing the change of each participant's views of the emphasized NOS aspects for the pre-, post-, and delayed post-instruction data for scenarios 1 and 2, respectively. Following is a discussion of these results in relation to each of the three emphasized NOS aspects. The discussion will mostly focus on participants' informed understandings for ease of presentation and interpretation. For each aspect, the development, retention and regression of participants' understandings are presented in relation to the first scenario (genetically modified food) and the second scenario (water fluoridation). First, we present the participants' pre- and post-instruction data, then the retention of participants' understandings from post-questionnaire to delayed post-questionnaire, followed by the regression in participants' understandings from post-questionnaire to delayed post-questionnaire for each of the two scenarios. Then, a comparison is presented between the two scenarios of the percentage of participants who improved their understandings of the emphasized NOS aspects from pre-questionnaire to post-questionnaire and then retained their acquired informed understandings from post-questionnaire to delayed post-questionnaire.

Subjective Aspect of NOS

Development of participants' understandings for scenario 1. Prior to the treatment, more than half of the participants held naïve understandings about the subjective aspect of NOS. When asked about the difference in scientists' conclusions as they look at the same data, these participants related the difference to features pertaining to the data and not to issues related to the scientists themselves. At the conclusion of the study, the understandings of more than half of the participants were improved for this aspect. As can be noted in the first example from the pre-questionnaire, the participant explained that scientists have different data and experiments and therefore they would have different conclusions. As for the second example from the post-questionnaire, the

Table 2. Percentage of participants with informed, intermediary, and naïve views of the emphasized NOS aspects for the pre-, post-, and delayed post-instruction data for scenarios 1 and 2

	Subjective NOS			Tentative NOS			Empirical NOS		
	Pre	Post	Delayed post	Pre	Post	Delayed post	Pre	Post	Delayed post
Scenario 1									
Informed	17%(4)	83%(20)	46% (11)	12%(3)	50%(12)	37%(9)	21% (5)	63%(15)	42%(10)
Intermediary	17%(4)	4%(1)	33% (8)	25% (6)	17% (4)	13% (3)	13% (3)	21% (5)	29% (7)
Naïve	66%(16)	13% (3)	21% (5)	63%(15)	33% (8)	50% (12)	66%(16)	16% (4)	29% (7)
Scenario 2									
Informed	21% (5)	79%(19)	46% (11)	8% (2)	42%(10)	29% (7)	17% (4)	58%(14)	37% (9)
Intermediary	17% (4)	4%(1)	33% (8)	25% (6)	21% (5)	25% (6)	17% (4)	17% (4)	29% (7)
Naïve	62%(15)	17% (4)	21% (5)	67%(16)	37% (9)	46% (11)	66%(16)	25% (6)	34% (8)

Table 3. Change of participants' views of the emphasized NOS aspects for the pre-, post-, and delayed post-instruction data for scenario 1

	Subjective NOS			Tentative NOS			Empirical NOS		
	Pre	Post	Delayed Post	Pre	Post	Delayed Post	Pre	Post	Delayed Post
S1	1	3	2	1	1	1	3	3	3
S2	1	1	1	1	1	1	1	3	3
S3	3	3	3	2	3	3	1	2	2
S4	1	3	3	1	3	1	1	3	3
S5	1	3	3	1	2	2	1	3	1
S6	1	3	3	3	3	1	1	3	1
S7	2	3	2	1	1	1	1	3	3
S8	1	3	2	2	1	1	3	3	2
S9	1	3	3	1	3	3	1	2	2
S10	1	3	2	1	3	3	2	3	1
S11	1	3	3	1	1	1	1	1	1
S12	1	3	3	2	2	1	1	2	2
S13	2	3	2	3	3	3	2	3	1
S14	3	3	3	3	3	1	3	3	3
S15	2	3	2	1	1	1	1	1	1
S16	1	3	3	1	3	3	1	3	3
S17	1	1	1	1	3	3	3	3	2
S18	3	3	3	1	1	1	1	2	3
S19	1	1	1	2	3	3	1	3	3
S20	2	3	2	2	3	3	1	3	3
S21	1	2	2	2	3	3	1	1	3
S22	1	3	1	1	2	1	3	3	2
S23	3	3	3	1	1	2	2	2	2
S24	1	3	1	1	2	2	1	1	1

Note: 3 = informed, 2 = intermediary, 1 = naïve.

participant was able to understand that scientists might have different interpretations when looking at the same data because of different perspectives and backgrounds:

> Yes, scientists would reach different conclusions because each one scientist has his own data and his own experiments. (S-22, pre-questionnaire, scenario 1)

> Scientists have different backgrounds → different perspectives → different interpretations → different conclusions. (S-11, post-questionnaire, scenario 1)

Retention of participants' understandings for scenario 1. The percentage of participants with informed understandings of the subjective aspect was 46% for the delayed post-questionnaire, compared to 83% and 17% in the post- and pre-questionnaire in that order. Figure 1 illustrates theses comparisons.

Following the retention period, 46% of the participants still demonstrated informed understandings of this aspect at the end of the study. For example, these participants

Table 4. Change of participants' views of the emphasized NOS aspects for the pre-, post-, and delayed post-instruction data for scenario 2

	Subjective NOS			Tentative NOS			Empirical NOS		
	Pre	Post	Delayed Post	Pre	Post	Delayed Post	Pre	Post	Delayed Post
S1	1	3	3	1	1	1	2	2	2
S2	3	3	2	2	3	3	3	3	3
S3	3	3	3	3	3	3	1	3	1
S4	2	3	2	1	3	3	1	2	2
S5	1	1	1	1	3	3	1	3	3
S6	1	3	2	2	3	2	2	3	2
S7	1	3	3	1	1	1	1	1	1
S8	1	2	2	1	2	2	1	2	2
S9	3	3	1	1	1	1	1	1	1
S10	1	3	3	1	3	3	3	3	2
S11	2	3	3	2	1	3	1	1	1
S12	1	1	1	2	3	2	1	3	3
S13	1	3	1	1	3	1	1	1	1
S14	1	3	2	1	2	2	1	3	3
S15	1	1	1	1	1	1	2	3	3
S16	1	3	3	1	3	1	1	3	3
S17	3	3	2	1	1	1	3	3	3
S18	1	3	3	1	2	2	1	1	1
S19	1	3	3	1	1	1	1	1	1
S20	2	3	3	2	1	1	2	3	1
S21	1	3	1	1	1	1	1	2	2
S22	3	3	3	1	2	2	1	3	3
S23	1	1	1	2	2	3	1	3	2
S24	2	3	3	3	3	1	3	3	3

Note: 3 = informed, 2 = intermediary, 1 = naive.

were still able to explain about the different interpretations by scientists when looking at the same data because of different backgrounds and/or experiences:

> Scientists can have different opinions and perspectives about it. Scientists start to guess but according to the data that they have about this information. They have different backgrounds and perspectives. (S-11, delayed post-questionnaire, scenario 1)

> This is because scientists come from different backgrounds and they also come from (a short pause) okay, I mean that they can also have different religions. This leads the scientists to react according to their beliefs, according to what they think and of course according to the scientific analysis. (S-9, delayed post-interview, scenario 1)

Regression of participants' understandings for scenario 1. Nine participants (37%) showed a decline in their understandings from post-questionnaire to delayed post-questionnaire in response to scenario 1. Seven of these participants reverted back in their informed understandings to the intermediary stage, while the remaining two

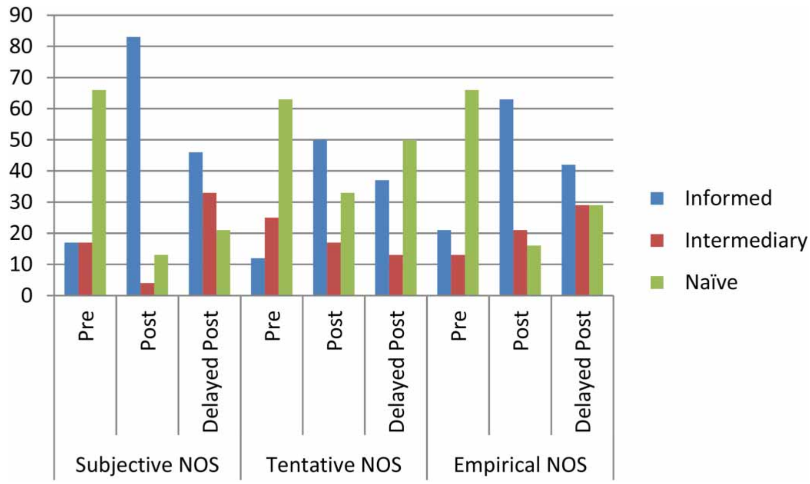

Figure 1. Comparisons of the percentages of participants with informed understandings of the three emphasized NOS aspects from pre-, post-, to delayed post-test for scenario 1

participants changed their informed understandings into naïve in the delayed post-questionnaire. For example, the participant S-22 reverted back to her naïve understanding after exhibiting more informed understanding in the post-questionnaire (as shown in Table 3):

> These scientists can have these different conclusions since they will have each their own questions and their own experiments. (S-22, delayed post-test, scenario 1)

> They [scientists] can have different perspectives and can look from different angles at the research and the experiment that they are experiencing. (S-22, post-test, scenario 1)

Development of participant's understandings for scenario 2. Similarly, there were major changes from pre- to post-questionnaire in participants' understandings of the subjective aspect in relation to the second socioscientific issue about water fluoridation. At the beginning of the study, participants attributed the difference in scientists' conclusions when looking at the same data to issues related to the questions, experiments, and/or data. By the end of the treatment, participants showed more understandings of the difference in scientists' conclusions when looking at the same data due to their different perspectives and interpretations, as shown in the example below:

> Each scientists has a different background, so each has a different opinion and perspective on the issue. (S-14, post-questionnaire, scenario 2)

Retention of participants' understandings for scenario 2. There was a decrease in the percentage of participants with informed understandings of the subjective aspect from 79% in post-questionnaire to 46% in delayed post-questionnaire, relative to 21% in the pre-questionnaire. These changes are more visible in Figure 2.

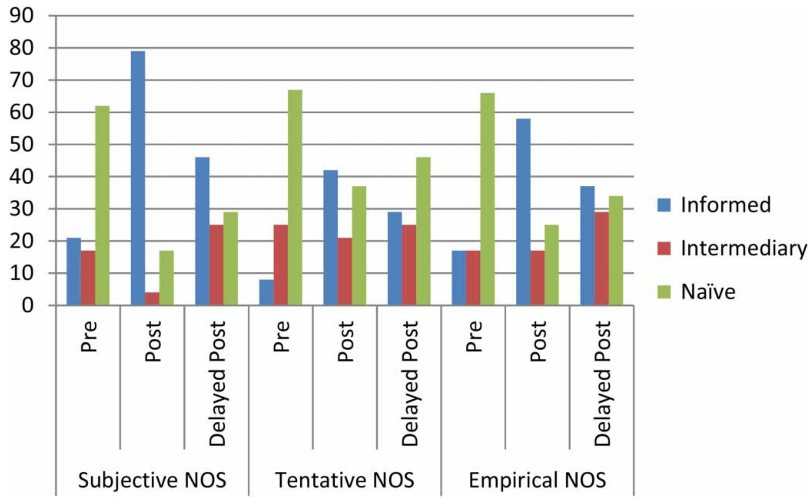

Figure 2. Comparisons of the percentages of participants with informed understandings of the three emphasized NOS aspects from pre-, post-, to delayed post-test for scenario 2

Four months following the treatment, less than half of the participants still showed informed understandings of the subjective aspect; they still related how scientist might reach different conclusions when looking at the same data owing to different background knowledge, personal experiences, and/or cultural biases:

> In general, scientists have different perspectives about the way they think about this problem of water fluoridation. So then different scientists can see the things differently, well that is because they maybe experienced something different or different beliefs, well even because of culture or religion. Then they work on their point to show it is true by supporting it with data. (S-7, delayed post-interview, scenario 2)

> Due to different perspectives and backgrounds, some scientists might overlook some factors and be biased to promote their findings. (S-19, delayed post-questionnaire, scenario 2)

Regression of participants' understandings for scenario 2. Eight participants (33%) showed a decline in their understandings from post-questionnaire to delayed post-questionnaire in response to scenario 2. Five of these participants reverted back in their informed understandings into intermediary and three participants changed their understandings into naïve. For example, S-14 is one of those who reverted back in their informed understandings into an intermediary one (Table 4). He stated that scientists can have different perspectives on the issue in his post-questionnaire response. He explained during the interview that 'scientists can look at the issues differently from different angles and so can have different perspectives'. However, his delayed post-questionnaire response showed that he was also entertaining an additional view that 'scientists might have done something wrong so got different conclusions'. He further explained in the delayed post-interview by stating that scientists 'might have looked at something in the wrong way so they got different conclusions …

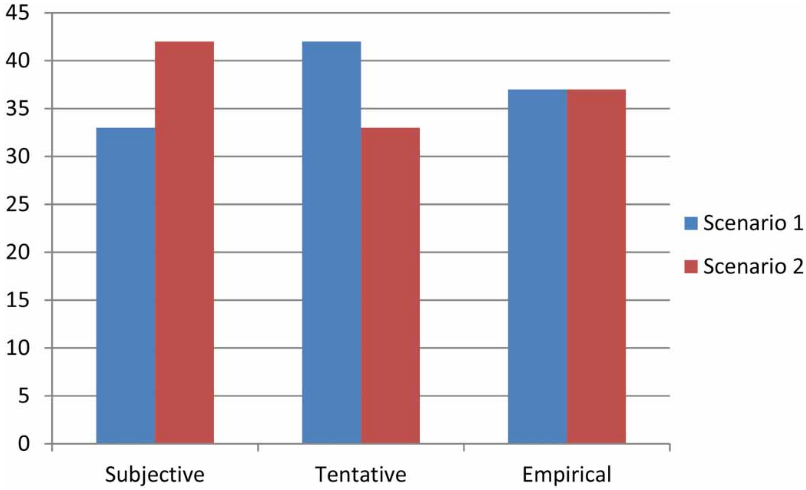

Figure 3. Comparisons of the percentage of participants who retained their acquired informed understandings of the emphasized NOS aspects between the two scenarios

they can have different perspectives at the issues … if they looked at it the right way, they would get same conclusion'.

Comparison of retention of acquired understandings between scenarios 1 and 2. Eight participants (33%), who improved their understandings of the subjective NOS aspect from pre-questionnaire to post-questionnaire, retained these acquired informed understandings from post-questionnaire to delayed post-questionnaire for the first scenario. In comparison, 10 participants (42%) improved and retained their acquired informed understandings of this aspect for the second scenario. A visual comparison that shows the correspondence between the two scenarios is provided in Figure 3.

Tentative Aspect of NOS

Development of participant's understandings for scenario 1. At the beginning of the study, more than half of the participants held naive understandings of the tentative aspect. The majority of these participants believe that scientific knowledge cannot change because it is 'true' and 'has already been proven'. Following instruction, half of the participants elucidated informed understandings of this aspect. The responses these participants provided were related to the role of new evidence and/or new interpretations of existing evidence, as shown in the following example:

> Yes, the knowledge about genetically modified food might change in the future if we find more research is done. And with more studies, there will be new interpretations are made so this would change what we already know. (S-9, post-interview, scenario 1)

Retention of participants' understandings for scenario 1. In comparison, participants' understandings of the tentative aspect developed tremendously, though they were not as pronounced as those of their improvements for the subjective aspect. There was a change in the percentage of participants with informed understandings of the tentative aspect from 12% to 50% then to 37% for the pre-questionnaire, post-questionnaire, and delayed post-questionnaire, respectively, for the familiar scenario about genetically modified food. Figure 1 clearly demonstrates these changes.

At the conclusion of the study, 37% of participants still showed informed understandings of this aspect. Their understandings were manifested when discussing that scientific knowledge might change in the future because of new evidence and/or different interpretations of the data, as illustrated in the following quotes:

> Scientists do not have absolute proof to assure them this is right. They make assumptions but assumptions are based on what they observe and the data they collect from their studies. (S-3, delayed post-questionnaire, scenario 1)

> Scientists do not have the absolute truth. Therefore, they do look at the data and then they deduce but they might deduce differently because think differently so their analyze [*sic*] might be different. (S-17, delayed post-questionnaire, scenario 1)

Regression of participants' understandings for scenario 1. Four participants (17%) regressed in their understandings of the tentative aspect from post-questionnaire to delayed post-questionnaire in response to scenario 1. Three of the participants reverted back into the naïve understandings that science is already proven and it symbolizes the absolute truth.

Development of participants' understandings for scenario 2. Prior to instruction, a majority of participants held naive understandings of the tentative aspect. Similarly, their responses related to the notion that scientific knowledge will not change, as this knowledge is 'true'. By the end of the study, participants exhibited more informed understandings, where they explained the change in the scientific knowledge about water fluoridation in terms of more evidence found by research:

> Yes, the knowledge about water fluoridation might change, it will because we will know more about effects of water fluoridation, well with the newly updated researches concerning the effects of water fluoridation. (S-6, post-interview, scenario 2)

Retention of participants' understandings for scenario 2. Similar results were found for the second scenario about water fluoridation. The proportion of participants with informed understandings of this aspect was 29% for the delayed post-questionnaire, compared to 42% and 8% in the post- and pre-questionnaire, respectively. Figure 1 illustrates these changes.

By the end of the four-month retention period, about one-third of participants still showed informed understandings of this aspect. These participants expressed the belief that scientific knowledge might change in the future and they explained that in terms of scientists finding new evidence and/or scientists looking at the data from new different perspectives and angles:

> They [scientists] aren't 100% sure, since that is science. If they do a new experiment that shows something different then that will change their recent information. (S-10, delayed post-questionnaire, scenario 2)

> [The knowledge about water fluoridation might change in the future] Yes, since science is not 'Absolute Truth,' further studies and research and technology can develop and will change knowledge about this issue. (S-4, delayed post-questionnaire, scenario 2)

Regression of participants' understandings for scenario 2. Five participants (21%) regressed in their understandings of the tentative from post-questionnaire to delayed post-questionnaire in response to scenario 2 as shown in Table 4. Two of these participants changed their understandings into intermediary and the other three participants reverted back in their informed understandings into naïve, as shown in the following example:

> What we have about water fluoridation, this knowledge will not change. It has already been established by scientists. (S-13, delayed post-questionnaire, scenario 2)

Comparison of retention of acquired understandings between scenarios 1 and 2. Ten participants (42%), who improved their understandings of the tentative NOS aspect from pre-questionnaire to post-questionnaire, retained these acquired informed understandings from post-questionnaire to delayed post-questionnaire four months later for the first scenario. In comparison, eight participants (33%) improved and retained their acquired understandings for the second scenario. A visual comparison that shows the similarity between is provided in Figure 3.

Empirical Aspect of NOS

Development of participant's understandings for scenario 1. At first, 66% of the participants held naïve understandings of the empirical aspect, where they did not understand the role of evidence involved in the production of scientific knowledge about genetically modified food. For example, the following participant related to scientists as 'authority' figures in the issue about genetically modified rice:

> The scientists themselves said that genetically modified rice can reduce blindness and I do believe those scientists because they know best. (S-2, pre-questionnaire, scenario 1)

When asked during the interview to explain his response, he simply replied that 'the word of scientists is enough for me and I believe whatever they say'.

By the end of the study, a majority of participants elucidated informed understandings of this aspect by explicating the role of evidence resulting from research as shown in the following example:

> It [golden rice] should not be promoted and marketed until we have studies that show the longer [*sic*] term side effects of genetically modified foods [*sic*]. (S-7, post-questionnaire, scenario 1)

Retention of participants' understandings for scenario 1. Major improvements were noted in participants' understandings of the empirical aspect from pre- to post-questionnaire (21–63%) with a decline to 42% for the delayed post-questionnaire. Figure 1 displays these changes.

By the end of the study, 42% of participants still showed informed understandings of this aspect. Their responses involved discussing the role of evidence or data in relation to the issue about genetically modified food:

> Scientific research might change what we know about genetically modified food. For example, if the new studies find effects about this issue of modifying the food then it will change the knowledge that we already know. (S-21, delayed post-questionnaire, scenario 1)

Regression of participants' understandings for scenario 1. Seven participants (29%) regressed in their understandings of the empirical aspect from post-questionnaire to delayed post-questionnaire in response to scenario 1. Three of these participants changed their informed understandings into intermediary and the remaining four participants reverted back in their informed understandings into naïve. For example, the following participant reverted back to a naïve understanding related to the absoluteness of science after his earlier belief about the role of evidence in the development of scientific knowledge about genetically modified rice (Table 3):

> The effects and what we know about genetically modified food cannot change. Science would not tell us something wrong or not sure about. (S-13, delayed post-questionnaire, scenario 1)

Development of participant's understandings for scenario 2. Initially, 66% of the participants held naïve understandings of the empirical aspect. Many of these participants related to issues of authority, such as FDA and scientists, rather than on evidence, as shown in the following example:

> I am satisfied with the water fluoridation situation and how it affects people. Everyone else should also be okay about it because this has been approved by FDA. (S-18, pre-questionnaire, scenario 2)

At the end of the study, 58% of participants exhibited informed understandings of the empirical aspect by emphasizing the role of empirical evidence involved in the change of scientific knowledge, as shown in the following example:

> This knowledge about effects of water fluoridation might change if the group against water fluoridation can actually back up their debates with actual evidence, so there needs to be more studies and research about this. (S-12, post-questionnaire, scenario 2)

Retention of participants' understandings for scenario 2. The proportion of participants with informed understandings of this aspect slightly decreased from 58% in post-questionnaire to 37% in delayed post-questionnaire, relative to 17% in the pre-questionnaire. These changes are noticeable in Figure 2.

Four months after the explicit NOS instruction, 37% of participants still elucidated informed understandings of the empirical aspect. These participants discussed the role of empirical evidence in the production, the development, and/or the change of scientific knowledge about issues related to water fluoridation:

> The knowledge [about water fluoridation] might change because newly updated research can provide more results on the effects of Fluoride on us humans. (S-15, delayed post-questionnaire, scenario 2)

Regression of participants' understandings for scenario 2. Five participants (21%) regressed in their understandings of the empirical aspect from post-questionnaire to delayed post-questionnaire in response to scenario 2 that addressed water fluoridation. Three of these participants changed their informed understandings into intermediary and the remaining two participants reverted back in their informed understandings into naïve. For example, participant S-23 changed his informed understanding into an intermediary one as shown in Table 4. In his post-interview, he explicated that scientific knowledge about water fluoridation might change in the future because of new studies that can provide new evidence. However, he did not seem very certain about this idea during the delayed post-interview. His response was considered intermediary as he discussed the evidence and then he changed his response and discussed the certainty of science as shown below:

> I believe water fluoridation might change in the future because of new studies that can provide new evidence so it will change the scientific knowledge but then I think that scientific knowledge cannot change … this is hard-care science so it should not change. (S-23, delayed post-interview, scenario 2)

Comparison of retention of acquired understandings between scenarios 1 and 2. Nine participants (37%), who improved their understandings of the empirical NOS aspect from pre-questionnaire to post-questionnaire, retained these acquired informed understandings from post-questionnaire to delayed post-questionnaire four months later for both scenarios. A clearer picture that shows the correspondence between the two scenarios is manifested in Figure 3.

Discussion

The aim of the study was to investigate the development and retention of students' acquired understandings of three emphasized NOS aspects four months following explicit instruction of NOS in relation to two contexts. For the first purpose of the study that related to the development of tenth graders' NOS understandings, results showed that the explicit NOS instruction enhanced students' understandings of

NOS in relation to the two contexts, which is not surprising and corroborate previous findings about the effectiveness of an explicit approach for teachers and students (e.g. Abd-El-Khalick, 2001; Abd-El-Khalick et al., 1998; Bell, Lederman, & Abd-El-Khalick, 2000; Khishfe & Abd-El-Khalick, 2002, Khishfe & Lederman, 2006).

As for the other purpose about the retention of acquired NOS understandings within the two contexts, results showed that many of the participants retained their acquired understandings of the emphasized NOS aspects. Those results support previous findings about retention in general showing that students were capable of retaining science concepts (Ozden & Gultekin, 2008; Sarikaya et al., 2010; Upadhyay & DeFranco, 2008). At the same time, there were many participants in the present study who reverted back to more naïve understandings at the end of the four-month retention period.

An additional focus of the study was exploring whether the retention of the acquired NOS understandings differ between the two scenarios about genetically modified food and water fluoridation. Results did not show any major differences between the retention related to the two scenarios. In previous research, it was found that the distribution of participants' responses was more significant in showing informed understandings for all three NOS aspects in relation to the scenario about water fluoridation compared to that about genetically modified food (Khishfe, 2012a). At the same time, previous research studies showed that learners hold different NOS understandings across different topics or domains (Abd-El-Khalick, 2001; Hofer, 2000, 2006; Khishfe & Abd-El-Khalick, 2002; Lederman & O'Malley, 1990; Sinatra, Sountherland, McConaughy, & Demastes, 2003). However, all these studies had no intervention, as was the case in the present study. It needs to be noted that the study by Khishfe (2012b) on which this study is based, found that participants did not conceive their NOS understandings differently when responding to the two scenarios following an intervention. That was evidence that participants transferred their NOS understandings from a familiar context to an unfamiliar context about water fluoridation. Furthermore, the retention of NOS understandings did not seem to be different in response to the two scenarios, as was evidenced in the data.

Given the present study's focus, the finding that at least about one-third of the participants retained some of their acquired NOS understandings of the emphasized NOS aspects after a four-month period is encouraging, yet very modest, especially with the regression in the NOS understandings of many participants. At the daunting side, there were also regressions in participants' understandings across the three emphasized NOS aspects. However, when we look at the bright side, it is heartening to find that participants, who retained the acquired informed understandings of the emphasized NOS aspects by the end of the study, were still more than the participants who held informed understandings of these NOS aspects at the beginning of the study. In other words, the study resulted in overall gains in the number of participants who acquired and retained their informed understandings of the emphasized NOS aspects. One must not forget that many factors might have affected the retention of acquired understandings. Therefore, the main findings of the study can be explained and interpreted in relation to the issues about the orientation to meaningful learning and prolonged exposure to the domain.

Orientation to Meaningful Learning

In the present study, the finding that many participants showed regression in their NOS understandings can be explained by relating to a key for retention, which is connection to prior knowledge. It appears that the connections to prior knowledge that these participants experienced were not strong enough. The intensity of connections between the student's prior knowledge and the new knowledge he/she is being exposed to has been determined as a key for long-term retention (Semb & Ellis, 1994). Theoretically, this process is interpreted by Gagne (1978) as follows:

> The process of long-term retention involves using an encoding of a probe stimulus to activate relevant portions of the propositional network. Because of the limited capacity and time-bound nature of the active part of the propositional network, the success of attempts to recall depends upon both the strength and the number of links leading to the to-be-remembered nodes. (p. 659)

A concerted effort was made in the present study to connect the themes to students' prior knowledge about science and scientists. How? For example, the teacher connected the students' activities and experiences to the work of scientists, which is something they are already familiar with. In other words, the teacher tried to connect the new knowledge about the nature of scientific knowledge in relation to the activities the students were experiencing by building bridges with the students' prior knowledge about the work of scientists. Nonetheless, the connections between the knowledge about the NOS aspects and students' prior knowledge were limited in the present study. It would be easier to learn and retain the new concepts that are connected to one's prior knowledge rather than concepts that are floating with no anchor.

This resonates with the claim by Upadhyay and DeFranco (2008) that when new information enters an abundantly connected and well-organized portion of the memory, it inherits all the connections that already exist. Again, this view overlaps with the model of meaningful learning (Ausubel, 1962) where the continued interaction of the new knowledge with the existing knowledge results in a longer retention span and that explains how rotely learned knowledge are more prone to forgetting, as it depicts the construction of flexible mental representations.

Prolonged Exposure to the Domain

Another way to interpret the results in relation to both the retention and regression experienced by many students is by way of the prolonged exposure to the domain, which has been suggested as another key determinant of long-term retention (Custers, 2010). The model of the NOS instruction (Khishfe & Lederman, 2006, 2007) adopted in the present study allowed students to engage in multiple reflective experiences about NOS aspects that were distributed across the unit, which might have helped in the retention of participants' acquired NOS understandings. The acquisition of these NOS understandings is paralleled with the prolonged periods and continuity of exposure to the content (Semb & Ellis, 1994). Custers (2010) proposed that the instructional content becomes more meaningful when the context provides for multiple and distributed opportunities for learning that coherently organize the content. That can be explained by the assertion that providing these multiple opportunities for practice would improve long-term retention either by strengthening links or by encouraging the formation of new links that can lead to the to-be-remembered nodes (Gagne, 1978) so that sections of the long-term memory attain a semi-permanent character (Bahrick, 1984). This has been addressed in the present study by having classroom discussions and written questions about the emphasized NOS aspects that were integrated within every other session throughout the unit. Along these lines, research has shown that performance is improved when practice sessions are distributed rather than massed (Bahrick & Hall, 2005). The phenomenon of spacing effect for the practice sessions has also been suggested as a means to enhance learning and optimize long-term retention of knowledge (Bahrick, 2000; Custers, 2010; Dempster, 1989). However, the intervention in the present study was not long enough to experience the spacing out for the explicit NOS sessions as NOS ideas were integrated within every other session. That might be another way to explain the inability of many participants to retain the acquired NOS understandings by the end of the study. Therefore, the intervention needs to be longer so that the multiple experiences of NOS instruction can be spaced out.

In summary, the present study adds significant contribution to the literature. First, it addressed the topic of retention in relation to NOS understandings. As noted earlier, this issue has not been addressed except for one study that explored the issue with pre-service teachers (Akerson et al., 2006). The present study adds to the knowledge base about retention especially at the student level. Second, the study pinpoints issues related to the retention and regression of students' NOS understandings along issues of meaningful learning and prolonged exposure to a domain. Hence, more planning and concerted efforts need to be implemented into interventions that target the retention of student learning.

Implications and Recommendations

The goal of promoting the retention of students' knowledge and skills acquired in schools to possibly use them in the future in their everyday lives is an important mission toward preparing citizens to live and survive with competence in the twenty-first century. With the little or nonexistent research on the retention of NOS understandings in particular, the present study is just the tip of the iceberg and there is much to be understood. The present results offer an encouraging and hopeful potential to better address the issue of retention, particularly of students' acquired NOS understandings following explicit instruction. Therefore, an important implication could be translated into better developing instruction to address and work toward this issue of retention. Consequently, the concern about retention ought to guide the classroom practice, where instruction becomes more meaningful and it needs to be 'polished' at several levels to get the best results. However, one need not forget that the present results are restricted to the participants and context within which this research was conducted. For that reason, there is a need for further studies to authenticate the present findings and also extend these findings to different grade levels and various topics. Another line of research that can be pursued might entail looking more closely and in isolation at each of the factors that can possible enhance retention, namely, (a) connecting the new knowledge about NOS to students' prior knowledge, (b) providing multiple distributed opportunities for explicit NOS instruction, and (c) spacing out the multiple experiences of explicit NOS instruction. These suggestions might provide future research venues for the issues of retention, particularly as it relates to the teaching and learning about NOS.

Disclosure statement

No potential conflict of interest was reported by the author.

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Appendix

Controversial Socioscientific Issues Questionnaire (CSI)

Scenario I

Scientists in the United Kingdom have developed a new genetically modified strain of 'golden rice' to deal with Vitamin A deficiency. The genetically modified rice plants contain two extra genes.

One group of scientists believe that eating the genetically modified rice with the two extra genes can help prevent blindness by improving vitamin A intake during digestion. As a result, this could help reduce childhood blindness, which affects 500,000 children worldwide each year especially in developing countries in Asia. This group argues that no studies have indicated any dangers associated with genetically modified foods.

Another group of scientists argue that we do not know how eating genetically modified rice (or any food) will affect us. There is no biochemical analysis of the golden rice to see how adding two genes may have changed the plant as a whole. Additionally, this group is concerned that the new rice is grown in the same regions as other rice so there might be crossing over (contamination), which would change the genetic material of other rice. So, these scientists argue that a healthily balanced diet would be a better solution than the golden rice to deal with the Vitamin A deficiency.

(a) As a scientist, do you think the golden rice should be produced and marketed?
YES NO MAYBE
(b) Explain and justify your decision
(c) How can you explain that scientists reached different conclusions even though they were all looking at the same data about genetically modified rice?
(d) Do you think the knowledge about genetically modified food might change in the future? Explain why or why not.
(e) As a scientist, do you think you might change your decision in the future? Explain why or why not
(f) Is there anything else you would want to know about this issue that might help you decide or even change your decision?

Scenario II

The fluoridation of water involves adding Fluoride to public drinking water. This issue is controversial and has been the cause for many court cases.

The group in favor of water fluoridation considers fluoridation as a safe and inexpensive way to prevent tooth decay for all citizens during their lifetime. They point out that many distinguished national and international scientific organizations support fluoridation. Further, this group argues that scientific research shows that water fluoridation reduces tooth decay and cavities and prevents dental disease.

The group against fluoridation considers it unethical because it is a form of involuntary medication; it violates people's rights, as they have no choice. They also point out that fluoridation does not have Food and Drug Administration (FDA) approval. Further, this group argues that scientific research shows harmful effects of fluoridation, such as possible links to cancer. Furthermore, adding Fluoride to drinking water makes it impossible to know how much Fluoride a person takes.

Your city plans on adding Fluoride to drinking water and requires residents to vote for or against this issue. If they get enough votes, then water fluoridation will be effective for the next five years.

(a) As a scientist, would you vote for adding Fluoride to drinking water in your city?
YES NO MAYBE
(b) Explain and justify your decision.
(c) How can you explain that scientists reached different conclusions even though scientists were all looking at the same data about the effects of water fluoridation?
(d) Do you think the knowledge about water fluoridation might change in the future? Explain why or why not.
(e) As a scientist, do you think you might change your decision in the future? Explain why or why not.
(f) Is there anything else you would want to know about this issue that might help you decide or even change your decision?